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REVIEW OF POSTAL AUTOMATION STRATEGY

A TECHNICAL AND DECISION ANALYSIS

A TECHNICAL MEMORANDUM

JUNE 1984

Technical Memoranda are issued by OTA on specific subjects analyzed in recent OTA reports or on projects presently in process at OTA. They are issued at the request of Members of Congress who are engaged in committee legislative actions which are expected to be resolved before OTA completes its assessment.

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Foreword

This OTA Technical Memorandum on postal automation responds to an October 5, 1983, letter of request from Congressman William D. Ford, Chairman of the House Committee on Post Office and Civil Service, Congressman Robert Garcia, Chairman of the Subcommittee on Postal Operations and Services, and Congressman Mickey Leland, Chairman of the Subcommittee on Postal Personnel and Modernization.

The Committee asked OTA to review the United States Postal Service (USPS) decision to utilize single-line optical character readers (OCRs) instead of multi-line OCRs, and to conduct a comparative technical and economic analysis of the two technologies in the context of the overall postal automation program. OTA did not assess the impacts of postal automation in other areas such as labor force requirements, mail processing organization, and privacy and security of the mail.

The Senate Committee on Governmental Affairs, Subcommittee on Civil Service, Post Office, and General Services, has also expressed an interest in this subject.

In preparing this memorandum, OTA has drawn on information and analyses from a variety of sources, including the October 1982 OTA report on Implications of Electronic Mail and Message Systems for the U.S. Postal Service. USPS has provided extensive materials on prior USPS automation studies as well as current operational data. The General Accounting Office has provided useful perspectives and analyses based on prior work and on a directly related study conducted in parallel with OTA's. On March 5, 1984, OTA held a postal automation workshop attended by mailers, manufacturers, and researchers who, along with USPS and GAO, participated in a vigorous discussion of key issues. Finally, OTA has benefited greatly from the excellent work of two OTA contractors -- Friendship Engineering Company for technical analysis and Decision Science Consortium, Inc. for decision and economic analysis.

OTA appreciates the participation of those who helped bring this study to fruition. The memorandum is, however, solely the responsibility of OTA, not of those who so ably advised and assisted in its preparation. Also, the purpose of this memorandum is to provide analysis and evaluation of options available to Congress and USPS, not to make recommendations as to which option(s) should be implemented.

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CONTENTS

Page

Foreword 1

Overview 2

Summary 6
  Summary of Technical Analysis 6
  Summary of Decision Analysis 8

Technical Analysis 13
  Alternatives to Optical Character Recognition 13
  Alternatives to a 9-Digit Zip Code 15
  Performance of Single-line Optical Character Readers (OCRs) 16
  Performance of Bar Code Sorters 18
  Performance of Multi-line OCRs 18
  Feasibility of Local and National Directories 22
  Feasibility of Single-line to Multi-line Conversion 25
  Technical Opportunities for Improved Performance 27

Decision Analysis 33
  Introduction 33
  Description of Decision Options 34
  Discussion of Key Assumptions 36
  Discussion of Key Uncertainties 41
  Results of Decision Analysis 51

Appendix A: Modeling Methodology 59

Appendix B: Detailed Cash Flow Models and Results 67

Selected References 98

LIST OF FIGURES

Table No. Page

1. Illustrative Optical Character Reader (OCR) Performance Data 16a
2. Productivity of Single- and Multi-Line Optical Character Readers 21a
3. Summary of USPS Equipment Upgrades.................................31a
4. Decision Options 34a
5. Uncertainties Included in Analysis of Decision Options 41a
6. Comparison of Code Usages 42a
7. Growth in ZIP+4 Usage Rate 43a
8. Estimates of 1989 Clerk/Carrier Savings 44a
9. Usage Savings Factors 46a
10. Estimated Percentage Rates of Return for Decision Options Under Various Conditions...52a
11. Estimated Net Present Values (in billions of dollars) for Decision Options Under Various Conditions 53a
12. Comparison of Net Present Values (in percentages and billions of dollars) of Options D, G, and H with Option A 54a
13. Eighty Percent Intervals on Net Present Value (Overall and Conditional) 54b
14. Cumulative Probability Distributions of Net Present Value (Smoothed) 56a
15. Sensitivity of net Present Value to Multi-Line OCR Purchase Cost 56b
16. Comparative Net Cash Flows, Selected Options and Conditions, 1985-1998 (in billions of dollars) 57a
17. Comparative Net Cash Flows, Selected Options, Conditions, and Years (in $ billions) 57b

A-1. Probabilistic Cash Flow Model 60
A-2. Simplified Representation of Continuous Probability Distribution 61
A-3 through A-7. Simplified Schematic Model for Options A through E 62-66

B-1 through B-4. Cash Flow Results for Options A through D 68-71

LIST OF TABLES

B-1 through B-19. Detailed Cash Flow Results 72-97

Overview

The United States Postal Service (USPS) is in the midst of implementing a major postal automation program. This program includes acquisition of a large number of optical character readers (OCRs) and bar code sorters (BCSs) along with adoption of the extended 9-digit ZIP code (known as ZIP + 4).

This postal automation program is intended primarily to reduce the amount of labor required to process mail, and secondarily to improve the quality of mail service. Since labor accounts for about 85 percent of total postal costs, reductions in the labor component of mail processing offer the greatest potential to cut current postal costs and restrain future cost increases.

USPS has already developed a national ZIP+4 directory, and since October 1, 1983, has been encouraging business mailers to use ZIP+4. Mailers receive a discount of 0.5 cent per piece of ZIP+4 presort first class mail when OCR-readable (can be read by optical character readers) and mailed in batches of 500 or more letters. For ZIP+4 non-presort first class mail, mailers receive a discount of 0.9 cent per piece, when OCR-readable and mailed in batches of at least 250 letters. Use of ZIP+4 is voluntary. At present, very few mailers (59 as of late May 1984) have converted to ZIP+4.

Use of ZIP+4 allows USPS to sort letters down to the city block, building, or post office box, whereas the 5-digit zip code permits sorting only to the level of a smaller post office zone or a geographical area within a larger post office zone. The optical character readers are intended to read the ZIP+4 code, translate it into a bar code, and apply the bar code (with an ink jet printer) to the lower right-hand corner of the envelope. From then on, the letter can be sorted automatically by bar code sorters down to the level of carrier routes. All intermediate manual sorting is eliminated.

To carry out the automated sorting, USPS has already bought 252 OCRs and 248 BCSs (Phase I of the automation procurement) at a combined cost (including ancillary equipment and installation expense) of $234 million. USPS expects this equipment to be fully installed and operational by the end of 1984. And USPS has received bids on procurement of an additional 403 OCRs and soon will be soliciting bids on an additional 452 BCSs (Phase II of the automation procurement). USPS has allocated $450.2 million for this procurement, of which $363 million is for capital expenditure.

The central issue addressed by this OTA technical memorandum is whether the current USPS automation strategy is technically and economically sound, and whether USPS should proceed to actual procurement of this equipment as planned or revise its strategy in whole or in part.

OTA concluded that **the current postal automation strategy, while technically feasible, is not likely to achieve the greatest projected economic return to USPS when the uncertainty in ZIP+4 usage is taken into account.**

USPS has based their strategy on achieving 90 percent ZIP+4 usage (among large business mailers) within 5 years, and 27 percent after 1 year. Current estimates indicate that first year (1984) ZIP+4 usage will fall far short of original USPS projections. Based on the preponderance of available evidence. **OTA concluded that it is quite unlikely that ZIP+4 usage will grow as fast as assumed by USPS.**

Therefore, while the current USPS strategy of using single-line OCRs would provide an economic return considerably greater than not automating at all, other strategies offer a better return on investment, net present value, and net cash savings than the current strategy, especially if one assumes ZIP+4 usage at the lower range of alternate projections.

These other strategies involve extensive use of a competitive technology -- the multi-line optical character reader. Whereas the single-line OCR can read only the "last line" of an address (defined as city, State, and 5- or 9-digit ZIP code), the multi-line OCR can read up to four lines of the address and can process a large amount of 5-digit ZIP mail to the 9-digit level. In other words, the multi-line OCR is not as dependent on use of ZIP+4 to realize savings from automation.

OTA concluded that, whereas the multi-line OCR may not have been a technically viable alternative 3 or 4 years ago when USPS made its initial decision to go with single-line OCRs, **the multi-line OCR is now fully competitive.** OTA found that the multi-line OCR performs as well as the single-line OCR in processing 9-digit ZIP mail, and significantly better than the single-line OCR in processing 5-digit ZIP mail to the 9-digit level. The purchase and/or conversion and maintenance costs of the multi-line OCR are expected to be only marginally higher than the single-line, and the difference is negligible when compared to the additional savings expected over the life of the investment.

Based on the results of OTA's cash flow modeling, the strategy offering the greatest economic return to USPS would be for USPS to proceed with the Phase II single-line OCR procurement, but simultaneously initiate release-loan testing (and any necessary related research and development) on single- to multi-line conversion, and then convert all single-line OCRs to multi-line as soon as possible, regardless of the level of ZIP+4 use. OTA has designated this the **automatic conversion** strategy.

Under conditions of high and median ZIP+4 usage, automatic conversion indicates a marginally greater ($40 to $180 million) net present value compared to the single-line OCR strategy. (Note: Net present value was calculated by discounting future cash flows at 15 percent per year.) But under low ZIP+4 usage, automatic conversion shows a substantially greater net present value of $250 to $820 million compared to single-line. As for total net cash flows (undiscounted) over the life of the investment (1985-98), at high ZIP+4 use, savings rate, and multi-line performance, automatic conversion shows a $560 million greater cash flow. All other things being equal, this increases to $790 million at median ZIP+4 usage and a dramatic $3.62 billion at low ZIP+4 usage, compared to single-line. In the out years (1994-98), under these conditions, automatic conversion shows a greater annual net cash flow in the range of $440 to $580 million.

In essence, the substantially greater performance and savings of the multi-line OCRs with non-ZIP+4 mail far more than offset the slightly higher conversion and maintenance costs, such that multi-line OCRs offer a clear economic (as well as technical) advantage over single-line OCRs. **Put more simply, if USPS were starting from scratch today, multi-line OCRs would appear to be the logical choice.**

The automatic conversion strategy assumes that conversion of single-line OCRs to multi-line capability is technically feasible and legally viable and could be accomplished with no degradation in performance. Questions have been raised as to whether the single-line OCR vendors would have the ability to do the conversions and/or whether other vendors -- perhaps more experienced with multi-line OCRs -- would be able to do the conversions without having access to proprietary information. A possible solution would be to reissue the Phase II request for proposals (RFP) with additional criteria on single- to multi-line convertibility and/or with a procurement split between single- and multi-line OCRs.

A split procurement would be intended to provide a stronger push to further improve multi-line OCR performance and perhaps provide a greater incentive for competition in the development of both multi-line OCRs and single- to multi-line conversion kits. OTA found that, overall, a 90-10 split procurement shows the second highest projected economic return, only marginally less than automatic conversion but higher than hedge conversion.

Under the 90-10 split procurement option, USPS would cancel the current Phase II procurement, immediately reissue an RFP for 90 percent of the single-line OCRs (363 instead of 403), and simultaneously initiate release-loan testing of the multi-line OCR. A new RFP for procurement of the other 10 percent of Phase II OCRs, but using multi-line technology (40 multi-line OCRs), would be issued as soon as possible, probably in about 2 years. The single-line OCRs (252 from Phase I and 363 from Phase II) would be converted to multi-line as soon as a conversion kit has been successfully developed and tested.

The 90-10 option would result in a delay of about 2 to 3 months in procurement of the 90 percent Phase II single-line OCRs (the time required to reissue the RFP and receive and evaluate new bids). Procurement of the other 10 percent would be delayed about 2 to 3 years (the time required to complete release-loan testing of, issue an RFP on, and receive and evaluate bids for multi-line OCRs). OTA found that the cost of this delay for 10 percent of the Phase II procurement is very small, and would be negligible if the split procurement resulted in significantly higher multi-line OCR performance than would otherwise be the case.

In sum, the 90-10 split procurement option is intended to reduce the uncertainty associated with automatic conversion by providing a greater incentive to companies to further improve multi-line OCR performance and to develop the best possible conversion kits.

OTA is not recommending one option over another, but simply pointing out the trade-offs involved. The automatic conversion shows the highest projected economic return, followed in order by the 90-10 split procurement, hedge conversion, and 50-50 split procurement. All of these options depend on conversion kits that provide high multi-line performance.

The principal question is how to stimulate development of the best possible conversion kit. OTA believes that some outside competition would help achieve this objective, and that it will be necessary to provide incentives to attract the best companies. One incentive is to keep open the decision on which company will do the conversions pending the results of several competitive development and testing efforts. This means that the best performing company would have a good chance for the conversion contract (estimated at about $130 million). A second incentive is the opportunity for participating companies to use the R&D results on the world market, even if USPS does not buy any multi-line OCRs. A third incentive would be the prospect of competing for the 10 percent of the Phase II procurement reserved for multi-line OCRs (estimated at $34 million) under a split procurement option.

Thus, a 90-10 split procurement option could involve several elements: reissuing the Phase II RFP for 363 (rather than 403) single-line OCRs; initiating competitive release-loan testing on multi-line OCRs; and awarding several development contracts for conversion kits, either all on a competitive basis or at least one on an open competitive basis even if the others are awarded sole source to Phase I and Phase II single-line OCR companies.

In addition to revising current automation strategy to give greater emphasis to multi-line OCRs, USPS may also wish to strengthen its commitment to research and development, which is still well below industry averages, and aggressively pursue further opportunities for improved performance of postal automation.

Summary

Summary of Technical Analysis

Alternatives to optical character recognition technology. As a starting point, OTA examined possible alternatives to optical character recognition for postal automation technology. Optical character recognition technology reads printed alphanumeric characters (letters and numbers) and recodes these characters into machine-readable forms such as a bar code.

OTA identified several electronic, magnetic, and mechanical alternatives to optical character recognition. However, OTA concluded that, at least for the U.S. mail, it is as yet difficult to improve on the information-carrying ability, readability, and cost effectiveness of printed characters on paper. As long as this is the case, then optical character recognition technology is the technology of choice.

Electronic mail is likely to be the strongest competitor of postal automation. But there most likely will be a significant residual volume of paper mail at least through the year 2000. Thus there is a window of opportunity for further USPS use of paper-based automation technology.

Alternatives to a 9-digit ZIP code. OTA found that there are alternative codes. However, OTA concluded that at this juncture there is no realistic alternative. The 5-digit ZIP is almost universally accepted and used (98 percent usage); the 9-digit ZIP directory is now completed; and ZIP+4 codes are being distributed to large business mailers.

If ZIP+4 becomes widely used, USPS could consider adding a tenth digit (for error checking purposes) at some future time. (Note: The USPS bar code already includes a correction character.) Only if ZIP+4 does not become widely used could alternative codes realistically be considered.

Performance of single-line optical character readers (OCRs). OTA reviewed available data on performance of the single-line OCRs now being installed by USPS. Single-line OCRs read only the last line of an address -- usually containing the city, State, and 5- or 9-digit ZIP code. OTA concluded that, despite initial start-up problems, the already installed OCRs now essentially meet USPS performance specifications.

Performance of multi-line OCRs. Over the last few years, multi-line OCR technology has emerged from the laboratory and prototype stage to operational units. Multi-line machines read up to four lines of the address.

OTA concluded that, as of May 1984, the preponderance of evidence indicates that multi-line OCR performance is essentially equivalent to single-line for reading 9-digit ZIP mail, and that multi-line performance is substantially better for reading 5-digit ZIP mail to the 9-digit level.* OTA identified one U.S. firm (Recognition Equipment, Inc.) and two foreign firms (Telefunken of Germany, ELSAG of Italy) that have proven multi-line OCRs.

OTA also concluded that USPS has probably underestimated the ultimate operational performance level of multi-line OCRs by 5 to 15 percent. USPS estimated that multi-line OCRs would process 60 percent of 5-digit mail to the 9-digit level. OTA believes that 65 percent is more likely and 75 percent possible.

Feasibility of local and national directories. In order to read, code, and sort 5-digit ZIP mail to the 9-digit level, multi-line OCRs require a computerized address directory against which the address information can be compared to ascertain the correct 9-digit ZIP code. They then apply the corresponding bar code, and finally sort the letter.

Until recently, the absence of a local or national directory was a limiting factor for use of multi-line OCRs. However, in the 1981-83 period, USPS completed a national ZIP+4 directory and local ZIP+4 directories for major metropolitan areas. USPS and OTA agree that the conversion of existing local ZIP+4 directories to a multi-line OCR format is technically feasible.

Whereas local directories clearly would be necessary for multi-line OCR operation, OTA was not able to determine whether national directories would offer any significant advantage, particularly when compared to the technical difficulties and likely additional cost.

Feasibility of single-line to multi-line conversion. OTA reviewed the technical feasibility and cost of converting single-line OCRs to multi-line. OTA concluded that conversion would be technically feasible and the USPS estimate of conversion cost -- $200,000 per machine -- is as good as can be developed from available information.

The actual cost of single- to multi-line OCR upgrade can only be determined by detailed engineering analysis and competitive procurement process. It is possible that the conversion could be accomplished by an OCR manufacturer other than the original source, although this might require a high degree of technical cooperation between the two vendors.

Technical opportunities for improved performance. OTA identified several areas where technical performance of postal automation might be improved in the future. These include bar-coded reply envelopes, mailer printing of bar codes, improvements in performance of optical character readers, standards for address format, and increased research and development on postal automation.

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* The full address with 5-digit ZIP is read and compared against a computerized address directory that includes 9-digit ZIP codes. If a match is made between the address on the envelope and an address in the directory, the appropriate 9-digit code is applied.

The USPS record on postal automation R&D is mixed. USPS continues to underspend on R&D compared to the U.S. industry average, and postal R&D organization and management appear to have lacked stability, clear direction and, at times, top level commitment. Despite 20 years of USPS investment in optical character recognition R&D, when USPS solicited manufacturers in 1980 for single-line OCRs, all U.S. manufacturers previously receiving USPS support for single-line OCR R&D had withdrawn from the market, in part due to several years of USPS indecision on an automation strategy.

On the other hand, USPS has established a good track record in narrowly focused R&D on improvements to upgrade existing equipment, such as the multi-position letter sorting machine. Also, despite some variability in funding and commitment, USPS has provided enough support over the last 14 years to Recognition Equipment, Inc. (REI) such that REI has developed one of the leading multi-line OCRs on the world market.

Summary of Decision Analysis

USPS faces a decision point as to whether to continue its commitment to ZIP+4 and single-line OCR technology or to modify that commitment in some way.

OTA employed decison analysis techniques to: identify the range of options available to USPS; develop a probabilistic cash flow model of each option; assign probability distributions for key variables such as ZIP+4 usage and multi-line OCR performance; and calculate the rate of return (ROI), net present value (NPV), total net cash flow, and annual net cash flow for each option; and conduct sensitivity tests of the results to changes in key variables.

Description of decision options.

- Option A: Phase II single-line OCR is the current USPS strategy to proceed to procurement of the 403 additional single-line OCRs advertised for Phase II of the postal automation program, and on which bids have already been received.* Under option A, there would be no further USPS expenditure on multi-line OCR research, development, and testing.

- Option B: Multi-line OCR with ZIP+4 is a decision to cancel the current Phase II single-line OCR procurement, initiate release-loan testing** of multi-line OCRs, and as soon as possible reissue the Phase II request for proposals but for multi-line rather than single-line OCRs, meanwhile retaining the ZIP+4 code. Single-line OCRs already purchased would be converted to multi-line capability.

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* OTA did not analyze the option of procuring 403 additional Phase I single-line OCRs instead of Phase II OCRs. This option was judged to be not significantly different from option A.

** The release-loan testing manufacturers actually test prototype equipment on USPS premises with real mail.

- Option C: Multi-line OCR without ZIP+4 is the same as option B except that the ZIP+4 code would be terminated. The 5-digit ZIP code would be retained.

- Option D: Automatic conversion is to proceed with the Phase II single-line OCR procurement, but simultaneously initiate release-loan testing (and any necessary related R&D) on single-line to multi-line conversion and then convert all single-line OCRs as soon as possible, regardless of the level of ZIP+4 use.

- Option E: Hedge conversion is similar to option D except that the single- to multi-line conversion would take place only if ZIP+4 use is low at a specified future time (defined here as year-end 1987). Both options D and E include the same initial decision to purchase Phase II single-line OCRs, and to initiate release-loan testing of and any necessary research on conversion. The difference is that under option D, the conversion would be made regardless of the level of ZIP+4 use, while under option E, conversion would take place only if use is low.

- Option F: Cancel Phase II and ZIP+4 is to cancel the Phase II single-line OCR procurement, terminate ZIP+4, and use the single-line OCRs already purchased to process 5-digit ZIP mail.

- Option G: 50-50 Split procurement is a hybrid option that would cancel the Phase II procurement, immediately reissue an RFP for one-half the number of single-line OCRs (202 instead of 403), and simultaneously initiate release-loan testing of the multi-line OCR and single- to multi-line conversion. A new RFP for procurement of the other half of the OCRs but using multi-line technology (201 multi-line OCRs) would be issued as soon as possible, probably in about 2 years, at which time the then existing single-line OCRs (252 from Phase I and 202 from Phase II) would be converted to multi-line.

- Option H: 90-10 Split Procurement is similar to option G except that the Phase II RFP would be reissued for 90 percent of the single-line OCRs (363), rather than 50 percent, and release-loan testing would be initiated on multi-line OCRs leading to a new RFP for procurement of the other 10 percent of the OCRs (40) using multi-line technology.

Key assumptions. Where possible and justifiable, OTA used the same assumptions as did USPS. For example, OTA and USPS used the same time horizon (14 years, 1985-98), labor cost escalation rate (7.42 percent annually), baseline cost and savings projections (for single-line OCRs, as presented in January 1984 to the Board of Governors), discount rate (15 percent per year), and single-line OCR performance and cost. OTA assumptions about multi-line OCR cost ($850,000 per machine), single- to multi-line conversion cost ($200,000 per machine), and the time required to release-loan test and procure multi-line OCRs and conversion kits (3 years) were generally consistent with USPS and GAO estimates.

The major differences between USPS and OTA were assumptions about the incentive rates for ZIP+4 usage (OTA and GAO treated these as a cost, since incentives appear to be required to get large mailers to use ZIP+4), multi-line OCR performance rates (OTA and GAO concluded that performance would likely be somewhat better than USPS estimated), ZIP+4 usage, and clerk/carrier savings rate.

For the latter three variables, OTA developed low, median, and high estimates. For low, median, and high estimates of multi-line OCR performance, OTA concluded that production model multi-line OCRs would read 60, 65, and 75 percent of 5-digit mail to the 9-digit level, respectively.

For ZIP+4 usage, USPS projects that usage would reach 90 percent of the machinable metered first class mail base within 5 years. This is considerably more optimistic than actual experience with either the U.S. 5-digit ZIP code or the Canadian 6-digit postal code. The 5-digit ZIP took 12 years to reach 90 percent usage; after 5 years, the 5-digit usage level was about 51 percent. Thus, the USPS projection shows ZIP+4 reaching 90 percent about two and one-half times as fast as the 5-digit ZIP (in 5 years rather than 12). At present, the projected actual volume of ZIP+4 mail for 1984 is about 20 percent of the original USPS projection.

After reviewing all available evidence, OTA concluded that the USPS ZIP+4 projection should be considered optimistic (high), that an appropriate median estimate would be the 5-digit ZIP growth pattern, and that an appropriate pessimistic (low) estimate would be a growth pattern peaking out at about 40 percent ZIP+4 usage. At the present time, the first year ZIP+4 usage could turn out to be even more pessimistic. The estimated 2.73 billion pieces of ZIP+4 first class mail at year end 1984 represents about 5.4 percent of the target mail base as compared to about 7 percent under the low scenario, 13 percent under the median, and 28 percent under the optimistic scenario. (GAO made no estimate of ZIP+4 usage but did find that businesses are still concerned about the cost of converting and whether the USPS presort discount will be modified because of ZIP+4.)

For clerk/carrier labor savings, OTA concluded that the USPS baseline estimate was probably somewhat optimistic, since the quality and mix of the OCR processed mail may be less than anticipated, and labor costs (e.g., for maintenance) may be more than expected. OTA assumed high, median, and low labor savings rates of 100 percent, 90 percent, and 80 percent of the USPS estimate.

Results of decision analysis. With respect to internal rates of return (ROIs), every option except option F (cancel), under all conditions modeled, shows an ROI above the 15 percent threshold established by USPS. OTA assumed, therefore, that under any scenario, the Phase I single-line OCRs already purchased would be kept in service. All ROIs, net present values, and cash flows were calculated net of cash flows associated with the Phase I single-line OCRs. Use of ROIs for decisionmaking has a serious limitation. When more than one option clears the hurdle rate (that is, has more than the minimum required ROI, in this case 15 percent), the ROI itself gives no indication of the cash flow differences of the various options as a basis for comparing the options. An alternative to ROI frequently used in capital investment decisionmaking is net present value (NPV). NPV discounts the cash flows of each option at the hurdle or threshold rate, in this study 15 percent.

Under conditions of high savings and high multi-line performance, option D (automatic conversion) has about a 5 percent and 11 percent higher NPV with high and median ZIP+ 4 usage, respectively, than option A (single-line OCR). At low ZIP+4 usage, all other things being equal, the option D advantage increases to a substantial 134 percent or about $820 million in NPV. At a low savings rate (along with low ZIP+4 usage and high multi-line performance), the relative advantage of option D over A increases further to about 310 percent although the absolute advantage decreases to about $650 million in NPV. Even at low multi-line performance, option D has 53 to 119 percent relative advantage in NPV and a $320 to $250 million absolute advantage in NPV, at a high and low savings rate, respectively. Option E (hedge conversion) has the same NPV as option A at high or median ZIP+4 usage and the same NPV as option D at low ZIP+4 usage.

Option H (90-10 split procurement) also has a higher NPV than option A under almost all conditions. Option G (50-50 split procurement) has a significant although somewhat smaller advantage over option A at low ZIP+4 usage. Option G has a 34 to 271 percent relative advantage in NPV and a $170 to $710 million absolute advantage in NPV at low ZIP+4 usage, depending on the multi-line OCR performance rate and savings rate.

The ranking of the options by NPV is summarized below:

Overall	NPV Rank	Low ZIP+4 Use	NPV Rank
Option D	1 highest	Option D	1 highest
H	2	E	2 (tie)
E	3	H	3
G	4	C	4
A	5	G	5
B	6	B	6
C	7 lowest	A	7 lowest

OTA found that the NPV results are not very sensitive to the purchase price of the multi-line OCR or the number of multi-line OCR units. An increase in the purchase price from $850,000 to $970,000 or an increase in the number of units from 403 to 444 (as estimated by GAO to be required if the entire Phase II procurement was switched from single- to multi-line OCRs) would reduce NPV by about $20 to $30 million.

Net present value appears to be the best basis for comparative quantitative evaluation of the decision options. However, the actual undiscounted net cash flows over the 13 year payback period (1985-1998) can provide another dimension to the evaluation. Option A (single-line) is estimated to show positive cash flows of $8.8, $8.24, and $3.57 billion at high, medium, and low ZIP+4 usage. At high ZIP+4 usage, option B (multi-line with ZIP+4) is somewhat lower at $8.14 billion, options D (automatic conversion) and H (90-10 split procurement) somewhat higher at $9.36 billion and $9.24 billion respectively, and option G (50-50 split procurement) about the same at $8.75 billion. The comparisons between options change relatively little at median ZIP+4 usage.

However, at low ZIP+4 usage there is a substantial difference in net cash flows. Option A (single-line) shows a net cash flow of $3.57 billion. But, depending on the multi-line OCR performance rate, options D (automatic conversion) and H (90-10 split procurement) show a net cash flow of $5 to $7.2 billion, or about $1.4 to $3.6 billion greater than option A. Option G (50-50 split procurement) shows about $1.1 to $3.3 billion greater cash flow than option A, and option B (multi-line with ZIP+4) shows about $0.8 to $3.0 billion greater cash flow than option A.

A comparison of yearly cash flows gives similar results. By 1994, all equipment will presumably have been installed (or converted) and up and running at optimal performance. Options B, D, G, and H will by that time look exactly the same -- all multi-line OCRs. The single-line OCRs procured under options D, G, and H will have been converted to multi-line capability. Option A will continue to be solely single-line OCRs.

With high ZIP+4 usage, option A shows an annual net cash flow of about $870 million to $1.2 billion from 1994 to 1998. Options B, D, G, and H show almost identical annual cash flows, only slightly higher by about $70 to $100 million per year. However, at low ZIP+4 usage, the differences again become substantial. With high multi-line performance, options B, D, G, and H show between $440 and $580 million per year additional net cash flow compared to option A, from 1984 to 1998. With median multi-line performance, the advantage of options B, D, G, and H over A ranges from $370 to $490 million per year. And even at low multi-line performance, the advantage over option A, while reduced, is still significant at $180 to $240 million per year.

Technical Analysis

Alternatives to Optical Character Recognition

As a starting point, OTA examined possible alternatives to optical character recognition technology for postal automation.

OTA concluded that the strongest competition to postal automation is likely to come from electronic mail. If a significant portion of the paper-based mailstream were to divert to either Generation II (electronic input-hardcopy output) or Generation III (electronic input and output) electronic mail, then the need for optical character recognition technology would be reduced. However, in a previous (1982) study of electronic mail and message systems, OTA found that, even under very optimistic assumptions about growth of electronic mail, there most likely will be a significant residual volume of paper mail at least through the year 2000.

Therefore, while electronic mail is a strong competitor of postal automation, the major effects of electronic competition are likely to be delayed for at least 10 to 15 years. From this vantage point, there is a window of opportunity for further use of paper-based automation technology.

Some leaders in the optical character recognition industry already recognize that "the current information revolution promises to replace the traditional media on which information has been carried (paper) with electronic media.... Thus, OCR provides a bridge between the Paper Age and the Information Age. It is a transitional system which aids users who have one foot in each era. But as the (electronic) Information Age matures, the role of OCR promises to diminish.... The irony is that OCR will be faced with increased opportunities before the electronic axe falls" (Schantz, 1983, p.7).

Optical character recognition technology reads printed alphanumeric characters (letters and numbers) and recodes these characters into machine-readable forms such as a bar code. There are other recognition technologies like magnetic or mechanical, but these seem clearly impractical for conventional mail.

For example, rather than showing addresses in black and white alphanumeric printing on envelopes, the address information could be stored in bits of information in magnetic stripes on the envelope, similar to credit cards and farecards. However, magnetic stripes are not readable by the human eye and would be difficult for senders to encode and receivers to decode. Another form of magnetic code is MICR (magnetic ink character recognition) used on bank checks. This code is readable but lacks alphabetic characters and requires special equipment. Alternatively, a mechanical code could be used. Thus, address information could be stored as punched holes in cards or tape attched to the envelope. These would be difficult to read and would require special punches.

In sum, while there are electronic, magnetic, and mechanical alternatives to optical character recognition, none are both readable and readily and cheaply available as a substitute at the present time. In the final analysis, OTA found that, at least for the U.S. mail, it is as yet difficult to improve on the information carrying ability, readability, and cost effectiveness of printed characters on paper. As long as this is the case, then optical character recognition technology is the technology of choice.

Alternatives to a 9-Digit ZIP Code

OTA also examined whether there are viable alternatives to the 9-digit ZIP or ZIP+4 code.

OTA concluded that there are alternative codes, and, indeed, some are used today by other countries. For example, both Canada and Britain use alphanumeric zip codes, that is, a combination of letters and numbers. Other code schemes have been suggested, for example, using individual telephone numbers as zip codes. Telephone numbers would permit sorting down to the level of each individual street address.

In 1976, USPS considered a wide range of alternative ZIP schemes, including scrapping the 5-digit ZIP, using an alphanumeric code, and adding a check digit (e.g., a tenth digit to the 9-digit code). USPS ruled out any change in the basic 5-digit ZIP, since almost all mail (about 94 pecent as of 1976) used a ZIP code. A change in the 5-digit code was judged by USPS to be unfair and excessively burdensome to mailers. This left the alternative of adding 3, 4 or 5 digits to the existing 5-digit codes. USPS elected to add 4 digits. Three was ruled out since this would have required an alpha or alphanumeric add-on. Five was likewise ruled out, since the additional digit, while helping to detect code errors and preventing letters from sorting to the wrong destination, would have increased mailing list information and maintenance cost. (The USPS bar code does contain a correction character.)

At the March 5 OTA workshop, several participants expressed the view that the current 9-digit ZIP was not the best code, but that it was too late to make any major changes. The 5-digit ZIP is almost universally accepted and used (98 percent usage) and the 9-digit ZIP directory is now completed. ZIP+4 codes are being distributed to and beginning to be used by large business mailers.

At this juncture, OTA concluded that there is no realistic alternative. If the ZIP+4 becomes widely used, USPS could consider adding a tenth digit (for error checking purposes) at some future time. If ZIP+4 does not become widely used, alternative codes could be considered.

Performance of Single-line Optical Character Readers (OCRs)

OTA reviewed available data on performance of the single-line OCRs now being installed by USPS. Single-line OCRs read only the last line of an address -- usually containing the city, State, and 5- or 9-digit ZIP code.

In the 1976-80 period, when the basic USPS automation program was developed, the single-line optical character reader was, in the opinion of USPS, the only proven equipment. Even so, in 1980 when USPS issued specifications for single-line OCRs, no U.S. manufacturer had OCRs meeting USPS specifications. As a result, and to meet USPS domestic content requirements, four foreign companies teamed with U.S. manufacturers who were licensed to produce single-line OCRs.

Two U.S. OCR manufacturers (under foreign license) were selected -- Burroughs (under license to NEC) and Pitney Bowes (under license to ELSAG) -- along with one bar code sorter (BCS) manufacturer, Bell and Howell.

Both OCR manufacturers experienced start-up problems in meeting USPS performance specifications. However, based on review of current performance data and on-site inspection, OTA concluded that the already installed OCRs now essentially meet USPS performance specifications. Illustrative OCR performance data are presented in figure 1.

Figure 1

Illustrative Optical Character Reader (OCR) Performance Data

Burroughs/NEC

Actual Test Results	Accept Rate	Throughput Rate	Error Rate
Meter Belt Mail	80.0%	28,500 pieces/hour	1.50%
Managed Mail	60.0%	31,300 pieces/hour	2.40%
Performance Specs			
Meter Belt Mail	62.1%	28,908 pieces/hour	2.37%
Managed Mail	53.4%	30,083 pieces/hour	2.00%

Pitney Bowes/ELSAC

Actual Test Results	Accept Rate	Throughput Rate	Error Rate
Meter Belt Mail	72.0%	28,500 pieces/hour	1.10%
Managed Mail	62.0%	30,500 pieces/hour	1.10%
Performance Specs			
Meter Belt Mail	67.1%	26,224 pieces/hour	1.50%
Managed Mail	57.8%	26,730 pieces/hour	1.50%

Definitions:

Accept Rate	- Percent of letters read by the OCR as a portion of the total fed into the OCR.
Throughput	- Total mail pieces fed through the OCR per hour.
Error Rate	- Percent of letters sent to the wrong pocket.
Meter Belt Mail	- High quality, generally OCR readable mail from large mailers.
Managed Mail	- Mail from other Post Offices containing widely variable levels of OCR readable mail.

Source: United States Postal Service: August 1983 2-week tests.

The 252 OCRs already purchased by USPS averaged $645,000 per unit in capital cost, although the Burroughs price was apparently significantly lower (approximately $300,000 per unit) than the Pitney Bowes price.

These prices include all OCR equipment (e.g., mail transport, optical character recognition unit, computer directory, ink jet printer, sorting stackers) plus installation, acceptance (equipment must perform to USPS specifications prior to acceptance by USPS), and 2 years worth of spare parts. There is no obvious explanation for the significant price difference between Burroughs and Pitney Bowes, since both manufacturers bid on the same number of units meeting the same technical performance specifications. USPS apparently split the procurement between two vendors in order to encourage future competition for subsequent procurements, but at an additional cost of about $37.8 million (126 units times the estimated $300,000 price differential between Pitney Bowes and Burroughs).

In the so-called Phase II procurement, USPS intends to purchase an additional 403 OCRs. Competitive bids have been solicited from four qualified U.S. manufacturers (all under license to foreign companies):

U.S. Manufacturers	Foreign Licensor
Burroughs	NEC (Japan)
Pitney Bowes	ELSAG (Italy)
Recognition Equipment Inc.	Toshiba (Japan)
ElectroCom	Telefunken (Germany)

USPS has budgeted for a capital cost of $660,000 per unit for the 403 OCRs. Bids have been received by USPS, but a selection decision and contract award(s) will not be made before late June 1984.

Performance of Bar Code Sorters (BCSs)

Performance of the BCSs has not been in dispute. USPS has already procured 248 units from Bell and Howell at a capital cost of approximately $129,000 each. The BCSs sort 24,000 to 28,000 letters per hour depending on the type of sort, with an accept rate of 96 percent. USPS plans to procure an additional 452 BCSs as part of the Phase II procurement, and has budgeted approximately $154,000 per unit. USPS has signed agreements with five BCS manufacturers to conduct release-loan tests during the summer of 1984. The manufacturers are:

Bell and Howell (U.S.)
Hotchkiss-Brandt Sogeme (France)
Leigh Instruments (Canada)
National Presort (U.S.)
Telefunken (Germany)

USPS will require that at least 75 percent of the machine cost be of domestic manufacture. Therefore, any foreign manufacturer whose equipment tests satisfactorily will have to license a U.S. company to produce all or most of the machines in order to qualify for the competitive procurement.

Performance of Multi-Line OCRs

Over the last few years, multi-line OCR technology has emerged from the laboratory and prototype stage to operational units. OTA examined available research and data on multi-line OCR performance. The major difference between single- and multi-line OCRs is that the multi-line machines read up to four lines of the address while the single-line machines read only the bottom line (with city, state, and ZIP).

At present, USPS has no definite plans for use of multi-line OCRs. However, USPS has largely funded the development of a multi-line OCR by Recognition Equipment Inc. (REI), a U.S. company based in Dallas, Texas. REI has a proven track record in optical character recognition technology and is a leading U.S. corporation in high performance OCRs.

There are a total of five prototype REI multi-line OCRs operating at postal installations (two in Chicago; one each in New York, Philadelphia, and Dallas). The REI OCRs are known as RCS/OCR for Read Code Sort/Optical Character Readers.

The computer software of the RCS/OCR is programed so that the address search is "bottom up." That is, the bottom line containing city, State, and ZIP code (5- or 9-digit) is read first, followed by the second line containing the street number and name, followed by the third (and, if necessary, fourth) line containing company name, office building, etc. The address information on the envelope is compared with information maintained in a computerized ZIP+4 address directory. Once a match between the address information on the envelope and in the directory is obtained, a bar code is applied to the envelope, which from then on is sorted automatically down to the carrier level. The multi-line provides additional redundancy since, for example, the street number and name as well as city and State can be cross-checked against the ZIP code.

A direct comparison between single- and multi-line machine performance is difficult, since the USPS has not subjected both machines to equivalent acceptance testing on a comparable mail base. REI had proposed comparative testing, but this suggestion was declined by USPS on the grounds that it would be unfair to other potential multi-line OCR manufacturers and would violate the ongoing competitive procurement process for single-line OCRs. USPS also asserts that the REI multi-line OCR did not meet USPS performance specifications in 1980, when USPS initially decided to use single-line OCRs, and that test results on the prototype multi-line OCRs were not available until April 1983, after USPS had decided to purchase single-line OCRs.

OTA did not itself investigate and has reached no conclusions on the OCR procurement history. However, OTA did conclude that, as of May 1984, the preponderance of evidence indicates that multi-line OCR performance is essentially equivalent to that of single-line OCR performance for processing 9-digit ZIP mail, and that multi-line performance is substantially better for processing 5-digit ZIP mail to the 9-digit level.

For 9-digit ZIP (ZIP+4) mail, USPS performance data indicate that the Burroughs and Pitney Bowes single-line OCRs and the REI multi-line OCRs all correctly read, code, and sort 98 to 99 percent of OCR-readable ZIP+4 mail. For purposes of mail flow analysis, USPS assumes 100 percent correct reading of ZIP+4 mail.

For 5-digit ZIP mail, both single-line and multi-line OCRs correctly read, code, and sort 98 to 99 percent correctly to 5 digits. However, only the multi-line OCR can read, code, and sort 5-digit ZIP mail to 9 digits.

USPS has estimated that the multi-line OCR can read, code, and sort 60 percent of 5-digit ZIP mail to 9 digits. USPS believes that this 60 percent estimate may be high, since USPS assumed that the total local metropolitan area would be included in the OCR computer directory. If the local directory has less than total coverage, the read-code-sort rate would be reduced. Also, USPS notes that adequate test data are not available on how the multi-line OCR performs two-stage encoding (e.g., placing a 5-digit bar code on a non-local letter at an originating post office and subsequently placing the

4-digit add-on bar code -- or the entire 9-digit bar code -- on the letter at the destination post office).

In contrast, OTA has concluded that the 60 percent USPS estimate may be low for the following reasons. First, full coverage computerized local address directories appear to be technically and economically feasible. USPS already has partial local directories in several metropolitan areas. Second, there is no evidence that two-stage encoding will pose a significant problem for multi-line OCRs. REI asserts that two-stage encoding can be accomplished with no significant degradation in performance. Third, it is reasonable to expect that production model multi-line OCRs would have improved performance compared to the prototype RSC/OCRs. USPS has found that single-line OCR performance improved 5 to 10 percent between prototype and production.

With respect to overall productivity, USPS has concluded that the single-line and multi-line OCRs are roughly equal. Average data from USPS performance reports are shown in figure 2.

In addition to REI, OTA has identified two other companies that manufacture multi-line OCRs: Telefunken (Germany) and ELSAG (Italy). Japanese firms may have the capability and interest, judging from their activity in the single-line OCR market. Other than REI, no U.S. companies are known to currently have multi-line OCR capability. At one time, Control Data Corporation, IBM Corporation, and Ford-Aerospace (Philco-Ford) all had single-line OCR products, and might have been able to develop multi-line OCRs, but left the business in the mid-1970's. Burroughs, Pitney Bowes, and ElectroCom have acquired single-line OCR capability under licenses to foreign manufacturers (NEC, ELSAG, and Telefunken, respectively).

Figure 2

Productivity of Single- and Multi-Line
Optical Character Readers

	Gross Accept Rate (%)	Throughput (pieces/hour)	Productivity (pieces/hour)
Burroughs Single-line OCR	52.8	22,324	8,527
Pitney Bowes Single-line OCR	51.8	19,305	9,127
REI Multi-line OCR	51.3	22,095	10,397

Definitions:

Gross Accept Rate - Pieces of mail accepted by the machine per hour divided by pieces of mail fed to the machine per hour.

Throughput - Pieces of mail fed through the machine per hour.

Productivity - Throughput divided by workhours to arrive at pieces of mail processed per work hour.

Source: United States Postal Service

While it is difficult to extrapolate from foreign experience to U.S. postal needs, due in part to major differences in the mail make-up and use of postal codes, multi-line OCRs appear to be performing well in other countries. ELSAG has 20 two-line OCRs operating in French post offices with an apparently very low error rate (0.1 to 0.5 percent). Telefunken has two- or three-line OCRs operating in Norway, the Netherlands, and Britain. The British Post Office reports that its one Telefunken three-line OCR is undergoing a field trial to be completed by December 1984, and is handling United Kingdom mail at rates between 28,000 and 30,000 letters per hour. Productivity and error rates are not known.

Feasibility of Local and National Directories

In order to read, code, and sort 5-digit ZIP mail to the 9-digit level, multi-line OCRs require a computerized address directory against which the address information can be compared to ascertain the correct 9-digit ZIP code, then apply the corresponding bar code, and finally sort the letter.

OTA has reviewed the current state-of-the-art in computerized directories to determine if such directories for postal purposes are technically and economically feasible.

Accordingly to USPS, about 40 percent of mail is local and 60 percent non-local. If a multi-line OCR is to process local mail to the 9-digit level at the originating post office, a local directory is needed. If a multi-line OCR is to process all mail (local and non-local) to the 9-digit level at the originating post office, a national directory is needed.

Until recently, the absence of a local or national directory was a limiting factor for use of multi-line OCRs. However, in the 1981-83 period, USPS completed a national ZIP+4 directory and local ZIP+4 directories for major metropolitan areas. The national directory is stored on a computer in San Francisco and is essentially the sum of all local directories.

In the four cities where multi-line OCRs are already operating (Chicago, New York, Philadelphia, Dallas), the local directories have been partially converted to a format usable by the multi-line OCRs. For example, the Philadelphia multi-line OCR uses a converted local ZIP+4 directory containing about 185,000 local ZIP+4 codes covering more than one-half of the addresses in the Philadelphia metropolitan area.

USPS and OTA agree that the conversion of existing local ZIP+4 directories to a multi-line OCR format is technically feasible. This would be simply an extension of the partial conversions already accomplished in the four cities noted above.

Whereas local directories clearly would be necessary for multi-line OCR operation, OTA was not able to determine whether national directories would offer any significant advantage. With local directories only, non-local mail would have to be processed by multi-line OCRs twice, once at the originating post office to the 5-digit level and a second time at the destination post office to the 9-digit level. A national directory would, in theory, eliminate the need for two-stage OCR processing. After the initial OCR processing, the ZIP+4 bar coded mail could bypass subsequent OCR processing and be handled entirely by the less expensive bar code sorters.

USPS argues that this would not result in a reduction in the number of OCRs, since these machines would still be needed for processing outgoing mail at the destination post office. In addition, USPS points out that when taken together, local directories in all major metropolitan areas would amount to a de facto national directory. Local mail (about 40 percent of the total) would be processed using a local directory in the originating post office, and non-local mail (the other 60 percent) would be processed using local directories in the various destination post offices.

Nonetheless, OTA estimated the technical and cost requirements of a national directory, even though the need for such a directory has not been firmly established.

The memory size of a national directory has been grossly estimated at 20 gigabits or 20 billion bits. A directory of this size would contain all 20 million ZIP+4 codes plus address information including street number and address, city, State, and, where necessary, building floor and suite numbers. The size could be reduced to include only the most frequently used ZIP+4 codes and related address information. For example, if 15 percent of ZIP+4 codes account for 75 percent of ZIP+4 code use, then a memory size of 3 billion bits might suffice.

Currently available magnetic disc memory technology can provide a 3 billion bit capacity at a cost of about $30,000. But the average access time appears to be too long. Optical disc and magnetic bubble memories have similar limitations. Large random access memories (RAMs) have fast access times (microseconds as compared to milliseconds) and may be the best approach. A 3 billion bit directory using 256K RAMs might cost on the order of $300,000 in 3 years (1987 dollars). If five OCRs shared each directory, then the cost per OCR would be about $60,000.

In sum, a national directory would be technically feasible with memory technology now coming on the market. A full national directory of 20 billion bits of information would be very expensive (about $4 million each in 1987), even if shared among five OCRs ($800,000 per OCR). If the memory size is reduced to 3 billion bits, the cost would be about $300,000 per memory, or $60,000 per OCR if used on a shared basis (as above).

In contrast, a local directory would require much smaller memory size (e.g., about 72 million bits for the Philadelphia metropolitan area). OTA estimated that the cost of a typical local directory would be about $20,000 (roughly $300,000 times 72 million/3 billion times a multiplier of 3x). At this low cost, sharing a directory among several OCRs may not be necessary. But if shared among five OCRs, the cost per OCR would be further reduced to about $4,000. In all likelihood, the capital cost of local directories would be small compared to either the total cost of multi-line OCRs or to the cost of directory data conversion and maintenance.

Feasibility of Single-line to Multi-line Conversion

OTA reviewed the technical feasibility and cost of converting single-line OCRs to multi-line. OTA concluded that conversion would be technically feasible and that the USPS estimate of conversion cost -- $200,000 per machine -- is as good as can be developed from available information.

Conversion is relatively simple because a large part of the single-line OCR could be retained almost as is, as discussed below.

Letter sorter -- no change.

Letter transport -- no change. The current mechanical transport is designed to move faced and bottom justified letters at a constant speed past an OCR window. This function is common to single- and multi-line OCRs and would not change.

"Prelook" window -- probably no change. The prelook is used to find the address location, and probably could be used as is.

Lenses and scanners -- probably no change if the scan height and pixel resolution are adequate. Otherwise, the OCR hardware from the lens system back (including "prelook") would need to be replaced.

OCR electronics -- probably some change needed to upgrade the image registers, recognition logic, etc. Since the multi-line OCR must process much more address information than the single-line OCR, the basic scanning and clocking rates may have to be increased. If the single-line OCR already captures three or four lines of the address at sufficient speed and resolution, then little or no change in OCR electronics would be needed -- only a change in computer software and directory.

Computer software -- change needed to upgrade the software so that multiple address lines could be processed in a "bottom-up" fashion, and the resulting data properly formatted and queued into the directory.

Computerized directory -- change needed to expand the directory from city, State, and ZIP+4 to include street number and name and, as appropriate, building floor and suite.

Ink jet printer and verifier -- probably no change needed with a local directory. If a national directory is used, the access and processing time may lengthen to the point where the ink jet printer and verifier (sprays the bar code on the bottom right-hand edge of each envelope) would need to be moved farther downstream in the transport path.

The actual cost of single- to multi-line OCR upgrade can only be determined by detailed engineering analysis and a competitive procurement process. It is possible that the conversion could be accomplished by an OCR manufacturer other than the original source, although this would require a high degree of technical cooperation between the two OCR vendors.

Technical Opportunities for Improved Performance

OTA identified several areas where techical performance of postal automation might be improved in the future. These include bar-coded reply envelopes, mailer printing of bar codes, character recognition upgrades, address format standards, and increased postal research and development.

Bar-coded reply envelopes. Mailers-- and especially large business mailers -- already frequently provide reply envelopes to customers, presumably to facilitate payment of bills such as those mailed out monthly by utility, telephone, and gas companies. Preprinting of the bar code along with the return address on the reply envelope would appear to be cost-effective, and could permit processing of business reply mail by the less expensive BCSs rather than OCRs.

Some business mailers are already preprinting bar codes. But in order for this to be successful, the bar codes must be readable by the Bell and Howell bar code sorters. That is, the color spectrum of the ink and location of the bar code on the envelope must match the capability and location of the photo-detector in the BCS. Also, in order to achieve savings by bypassing some or all OCR processing, the bar-coded reply envelopes would need a unique facing indicia mark (FIM) so that these envelopes could be detected (perhaps by the facer/canceler) early in the mailstream and diverted to BCSs.

Mailer printing of outgoing bar codes. Most major business mailers already use computers to store, update, and print out addresses on outgoing mail. Addresses are printed directly on the envelopes, on mailing labels, or on letters that show through window envelopes. Almost all business mailers have already entered the 5-digit ZIP codes into their address data bases. USPS would, of course, like them to convert the addresses from 5-digit to 9-digit ZIP codes.

At present, few mailers have actually converted their address files, partly because of concern over the cost of conversion. Some participants at the March 5 OTA workshop pointed out that, if and when mailers convert, consideration should be given to building in a capability to print outgoing bar codes in addition to or as a substitute for the ZIP+4 numeric codes. In principal, outgoing bar-coded mail could, with proper FIMs on the envelopes, bypass the OCRs completely and go directly to BCSs.

In practice, the technical and economic feasibility is unclear. For example, high speed non-impact printers (such as laser printers) could be programed to print the bar code immediately under the last address line on an envelope or label. However, if the bar code location is too far up from the bottom of the envelope, then the Bell and Howell bar code sorters used by USPS would not be able to read the bar code unless a second scanning channel was added. Ink jet printers or special photo offset printing devices could also be used, but this would involve significant equipment procurement and processing changes on the part of mailers. And proper location of the bar code could be difficult when labels or window envelopes are used. Special bar code window envelopes or bar code labels might be needed. Bell and Howell indicated to OTA that addressing and/or inserting machines could be easily used to print bar codes on outside envelopes of outgoing mail, and that 30 to 35 billion pieces of mail annually could be processed in this way. A clear understanding of the potential and pitfalls must await further study.

Character recognition upgrades. The percentage of OCR-readable mail actually read by the single-line OCRs used by USPS, although meeting USPS performance specifications, is still far less than 100 percent. USPS has assumed an average read rate of 70 percent. One way to improve performance is to upgrade the character recognition technology.

Current character recognition technology uses mask matching, whereby character patterns are stored in electronic memory and matched against the actual characters in the address. But because there are so many different sizes, shapes, and forms of alphanumeric characters in U.S. mail addresses, not all characters are stored in electronic memory. If the computer cannot make a match within 100 milliseconds, the address is not read.

The overall read rate could be improved by, first, studying the rejected addresses and determining what types of characters are not being read. Then, OCR manufacturers could be solicited to develop improved character recognition technology that would read some or all of the characters rejected most frequently.

Address format standards. Some OCR rejects are due to problems with the location and format of addresses on envelopes. To receive a ZIP+4 discount, mailers must meet several mandatory requirements. These include: a bar code clear zone (at the bottom right-hand portion of the envelope) in which no printing or markings whatsoever are permitted; an OCR read area in which the city, State, and ZIP+4 code line must be visible and unobstructed (no extraneous printing or markings); machine-printed address with uniform character single and line spacing; and a reasonable degree of color contrast between the address and mail piece.

However, there are several voluntary guidelines with respect to margins; State abbreviations; character fonts; character pitch, height, and height to width ratio; character and line skew; upper case characters; and line and character spacing. Also, while black ink on white paper is preferred, other color combinations are permitted (except for brilliant colors and reverse printing and any others that do not meet minimum reflectance standards).

The overall read rate could be improved by studying the rejected address and determining the cause(s). The most common causal factors could be mitigated by:

1. better enforcement of mandatory format requirements;
2. improved compliance with voluntary format requirements, possibly through incentives, and if necessary, by making some voluntary requirements mandatory; and/or
3. technical upgrades as discussed previously, so that the OCRs can read a wider variety of address characters and formats.

Postal research and development. The USPS record on postal automation R&D is mixed. On the negative side, USPS continues to underspend on R&D, despite repeated recommendations from congressional oversight committees and the Commission on Postal Service to raise postal R&D closer to private sector levels. Postal R&D was about $24 million in 1983, or about one-tenth of one percent (0.1 percent) of revenue. This compares to a U.S. industry average of perhaps 3 percent. Second, postal R&D organization and management appear to have lacked stability, clear direction, and, at times, top-level commitment. Third, despite 20 years of USPS investment in optical character recognition R&D, when USPS solicited manufacturers in 1980 for single-line OCRs, no U.S. manufacturer was judged to be qualified. All U.S. manufacturers previously receiving USPS support for single-line OCR R&D had withdrawn from the market by 1980, in part due to USPS indecision on an automation strategy.

For example, USPS awarded development contracts for first generation OCRs to Philco Corporation in 1960-65, and for second generation OCRs to IBM and Philco-Ford in 1968 and 1969, respectively. Both companies developed successful OCR designs and were subsequently awarded prototype contracts. The Philco-Ford second generation OCRs were installed in Boston in November 1971 and successfully tested in early 1972; and IBM OCRs were installed in New York in June 1972 and tested in late 1972. By the time USPS had settled on a postal automation strategy and solicited manufacturers to provide OCRs on a release-loan basis in 1979-80, the only companies left in the single-line OCR business were foreign manufacturers. This was despite the fact that the Philco-Ford second generation OCR units in Boston remained operational until 1982, and the IBM OCR units in New York are still in service.

Thus, it is at least arguable that USPS could have reasonably opted for wide deployment of single-line OCRs in the early 1970's, perhaps using a 5-digit bar code (5-digit ZIP code use had reached 84 percent by 1972). Had USPS opted for this strategy, some U.S. manufacturers of single-line OCRs might well have stayed in the business. And it would be reasonable to expect that OCR technology would be further advanced than it is today.

On the positive side, USPS has established a good track record in narrowly focused R&D on improvements to upgrade existing equipment. For example, the multi-position letter-sorting machine (MPLSM), in wide use since the late 1960's, has been upgraded several times, most recently by a not yet fully implemented electronic ZIP retrofit (known as EZR) that allows four-digit keying of ZIP+4 codes. Facer cancellers, single position letter sorting machines, and flat sorting machines also have been, or will be, upgraded. USPS equipment upgrades are highlighted in figure 3.

Figure 3

Summary of USPS Equipment Upgrades

Multi-position Letter Sorting Machine (MPLSM)

1969 - ZIP Mail Translator (ZMT) - Converted MPLSMs from simultaneous keying (cordal) to sequential keying. ZIP Codes keyed by operators then could be translated by the ZMT into BIN assignments.

1973 - Engineering Data Isolation Technique (EDIT) - An electronic modification to the ZMT which allowed keyed data to be monitored for accuracy.

1974 - Automatic Density Analysis Profile Technique (ADPT) - An upgrade that enabled automatic tabulation of MPLSM sweepside BIN densities.

1976 - Electronic Sort Processor (ESP) - A modification to MPLSMs which replaced mechanical code setting with electronic code setting to provide more accuracy, reduce maintenance costs, and reduce noise.

1978 - Micro-Key - An upgrade to the ZMT which allowed the first digit of a carrier route number to be locked in each time an operator keyed an incoming secondary distribution.

1981 - ZIP Data Logger (ZDL)

1982 - Electronic ZIP Retrofit (EZR) - A modification to MPLSMs to allow four digit keying of ZIP+4 Codes.

Facer Cancelers

1982 - Micro Mark - A modification to Mark II Facer Cancelers to upgrade the electronics to Solid State circuitry.

Single Position Letter Sorting Machine (SPLSM)

1972 - Automated Business Mail Processing System (ABMPS) - A modification to the Universal Business Machine (UBM) SPLSM to allow automated distribution of destinating Bar Coded Business Mail.

Flat Sorting Machine (FSM 775)

1984 - Software Modification - An upgrade to provide Micro key capability on the FSM 775.

Source: United States Postal Service

Also on the positive side, despite some variability in funding and commitment, USPS has provided enough support over the last 14 years to Recognition Equipment,Inc. (of Dallas, Texas) such that REI has developed one of the leading multi-line OCRs on the world market. Ironically, at various times from the late 1960's to the late 1970's, USPS appeared to actually favor the multi-line over the single-line OCR. In the late 1970's, USPS procured one multi-line OCR from REI, and as insurance solicited every known OCR manufacturer in the world to provide a single-line OCR on a release-loan basis.

As it turned out, the REI multi-line OCR did not satisfy USPS performance requirements, but the single-line OCRs of five foreign manufacturers did (ELSAG, NEC, Telefunken, Toshiba, and ITT Belgium). USPS decided to deploy single-line OCRs and awarded production contracts to Pitney Bowes (under license to ELSAG) and Burroughs (under license to NEC) in early 1981. According to USPS, for insurance purposes an additional contract was awarded to REI for five multi-line OCRs. These were installed and tested between June 1982 and April 1983. As discussed earlier, USPS test data indicate that the multi-line OCR performance is now fully competitive with single-line OCR performance.

Finally, USPS may wish to consider: (1) new approaches to R&D and procurement (including the release-loan testing process) with a view towards speeding up the time delay from R&D to installation of new equipment; and (2) new ways to organize mail processing in order to achieve faster and more reliable delivery.

Decision Analysis

Introduction

USPS is approaching a critical decision point on postal automation strategy. At present, the USPS commitment is to the 9-digit ZIP and single-line OCR. USPS has developed 9-digit ZIP codes (ZIP+4) for the entire United States and prepared a national ZIP+4 directory, although as yet very few mailers are using ZIP+4. Also, USPS has procured and is installing Phase I automation equipment (including 252 single-line OCRs and 248 BSCs) and has received bids on an additional 403 single-line OCRs as part of a Phase II procurement. A selection decision is pending.

However, multi-line OCR technology has advanced to the point where it is fully competitive with single-line OCRs with respect to technical performance in processing ZIP+4 mail. In addition, multi-line technology offers a significant technical performance advantage over single-line OCRs in processing 5-digit ZIP mail to the 9-digit level.

Thus USPS faces a decision point as to whether to continue its commitment to ZIP+4 and single-line OCR technology or to modify that commitment in some way.

In order to analyze the USPS decision, OTA has employed decision analysis techniques to: identify the range of options available to USPS; develop a probabalistic cash flow model of each option; assign probability distributions for key variables such as ZIP+4 usage and multi-line OCR performance; calculate the rate of return (ROI), net present value (NPV), total net cash flow, and annual net cash flow for each option; and conduct sensitivity tests of the results to changes in key variables.

The options and assumptions used in the decision analysis along with the major results are discussed below. Further details on the modeling methodology and the complete cash flows for each option are included in the appendices.

Decription of Decision Options

OTA identified eight major decision options. These are listed in figure 4 and described below.

Option A: Phase II Single-Line OCR. Option A is the current USPS strategy to proceed to procurement of the 403 additional single-line OCRs advertised for Phase II of the postal automation program, on which bids have already been received. Under option A, there would be no further USPS expenditure on multi-line OCR research, development, and testing.

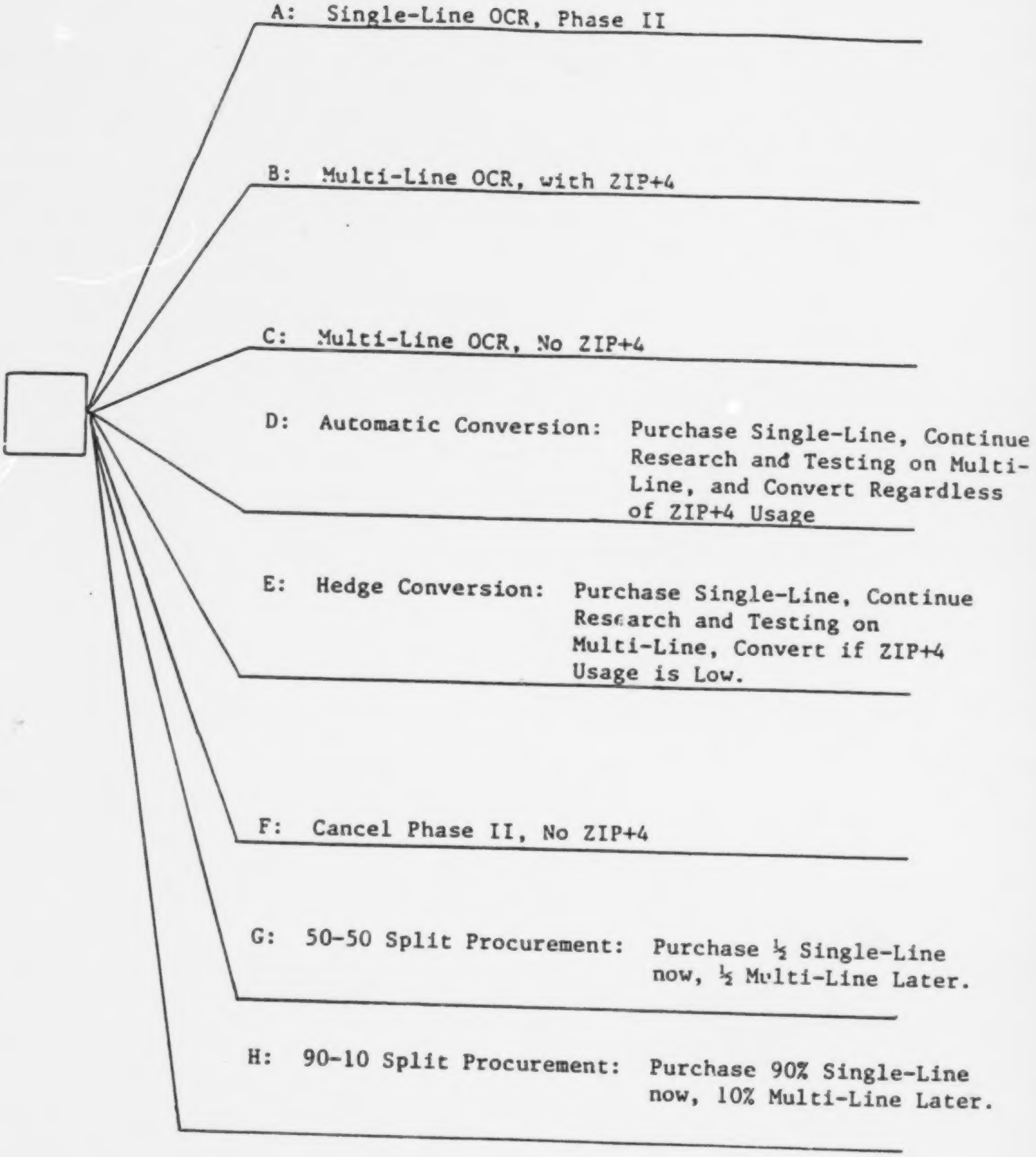
Option B: Multi-Line OCR with ZIP+4. Option B is a decision to cancel the current Phase II single-line OCR procurement, initiate release-loan testing (where manufacturers actually test prototype equipment on USPS premises using real mail) of multi-line OCRs, and as soon as possible reissue the Phase II request for proposals but for multi-line rather than single-line OCRs, meanwhile retaining the ZIP+4 code. Single-line OCRs already purchased would be converted to multi-line capability.

Option C: Multi-Line OCR without ZIP+4. Option C is the same as option B except that the ZIP+4 code would be terminated. The 5 digit ZIP code would be retained.

Option D: Automatic Conversion. Option D is to proceed with the Phase II single-line OCR procurement, but simultaneously initiate release-loan testing (and any necessary related R&D) on single-line to multi-line conversion, and then convert all single-line OCRs as soon as possible, regardless of the level of ZIP+4 use.

Figure 4

Decision Options


A: Single-Line OCR, Phase II
B: Multi-Line OCR, with ZIP+4
C: Multi-Line OCR, No ZIP+4
D: Automatic Conversion: Purchase Single-Line, Continue Research and Testing on Multi-Line, and Convert Regardless of ZIP+4 Usage
E: Hedge Conversion: Purchase Single-Line, Continue Research and Testing on Multi-Line, Convert if ZIP+4 Usage is Low.
F: Cancel Phase II, No ZIP+4
G: 50-50 Split Procurement: Purchase ½ Single-Line now, ½ Multi-Line Later.
H: 90-10 Split Procurement: Purchase 90% Single-Line now, 10% Multi-Line Later.

Source: Office of Technology Assessment

Option E: Hedge Conversion. Option E is similar to option D except that the single- to multi-line conversion would take place only if ZIP+4 use is low at a specified future time (defined here as year-end 1987). Both options D and E include the same initial decision to purchase Phase II single-line OCRs, and to initiate release-loan testing of and any necessary research on conversion. The difference is that under option D, the conversion would be made regardless of the level of ZIP+4 use, while under option E, conversion would take place only if use is low.

Option F: Cancel Phase II and ZIP+4. Option F is to cancel the Phase II single-line OCR procurement, terminate ZIP+4, and use the single-line OCRs already purchased to process 5 digit ZIP mail.

Option G: 50-50 Split Procurement. Option G is a hybrid option that would cancel the Phase II procurement, immediately reissue a Request for Proposals (RFP) for one-half the number of single-line OCRs (202 instead of 403), and simultaneously initiate release-loan testing of the multi-line OCR and single- to multi-line conversion. A new RFP for procurement of the other half of the OCRs but using multi-line technology (201 multi-line OCRs) would be issued as soon as possible, probably in about 2 years, at which time the then existing single-line OCRs (252 from Phase I and 202 from Phase II) would be converted to multi-line.

Option H: 90-10 Split Procurement. Option H is similar to option G except that the Phase II RFP would be reissued for 90 percent of the single-line OCRs (363), rather than 50 percent, and release-loan testing would be initiated on multi-line OCRs leading to a new RFP for procurement of the other 10 percent of the OCRs (40) using multi-line technology.

Discussion of Key Assumptions

In developing and modeling the decision options, OTA made a variety of assumptions. The starting point for the OTA analysis was the January 1984 cost, savings, and cash flow projections for single-line OCR procurement (and related equipment including bar code readers and extended ZIP retrofit kits) provided by USPS to the Postal Board of Governors. Using the USPS data as a base, key assumptions were adopted as is or modified as necessary to fit the decision options analyzed by OTA. These key assumptions are discussed below by option or groups of options.

All Options

- Time horizon. OTA assumed a 14-year time horizon, the same as was used by USPS. Thus, cash flows and ROI/NPV are calculated for the 1985-1998 time period.
- Labor cost escalation rate. OTA assumed a 7.42 percent annual escalation in clerk/carrier labor costs, as was used by USPS. This escalation rate is based on a 10-year historical average.
- Baseline cost and savings projections. OTA used the USPS cost and savings projections for single-line OCRs and related equipment. These projections were adjusted for the various options depending on extent and timing of single-line OCR deployment and uncertainties (where applicable) in ZIP+4 use and savings rate.
- Discount rate. OTA assumed a 15 percent discount rate (or required ROI), as was used by USPS. Compared to the U.S. Government's cost of capital (estimated to be 12.0 to 12.4 percent based on yields on U.S. Treasury bonds maturing in 1998-2001), the USPS discount rate appears to be reasonable.
- Phase IIA procurement. USPS has identified a possible future procurement of automation equipment as Phase IIA. OTA has excluded this from all options and limited analysis to Phases I and II.

All Options Using ZIP+4 (Options A, B, D, E, G, H)

- Incentive rates for ZIP+4 use. OTA assumed that the incentive rates offered to volume mailers who use ZIP+4 (0.5 cent for presorted first class and 0.9 cent for nonpresorted first class) is a cost. USPS argues that this is a return to mailers and thus a benefit of ZIP+4, not a cost. However, OTA concluded that the incentive rates are required to get large mailers to convert to ZIP+4, and are therefore appropriately considered a cost. OTA assumed a fixed incentive rate, and that escalating rates would not be necessary to maintain a given level of ZIP+4 usage. Based on these incentives and a detailed mail flow analysis, the General Accounting Office (GAO) estimated an annual cost for incentive rates of $140 million at 90 percent ZIP+4 usage (GAO, 1983a, p.152). OTA assumed the GAO estimate, with the cost reduced proportionately at lower ZIP+4 usage levels.

- Savings as a function of ZIP+4 use. OTA assumed for these options that some portions of clerk/carrier savings resulting from automation is a function of the level of ZIP+4 use. For single-line OCRs, OTA used the curve of savings versus ZIP+4 use developed by USPS. For multi-line OCRs, OTA assumed that the USPS curve was pessimistic and developed additional curves (median and optimistic). These curves are presented and discussed in a later section.

All options using multi-line OCRs (Options B, C, D, E, G, H).

- OTA concluded that USPS assumptions about multi-line OCR performance were pessimistic with respect to the multi-line OCRs ability to read, code, and sort 5-digit ZIP mail to the 9-digit level. OTA developed additional curves, as noted above and discussed later.

All options using single- or multi-line OCRs (options A, B, C, D, E, G, H).

- OTA concluded that the USPS baseline estimates of clerk/carrier savings were likely to be optimistic, for a variety of reasons discussed later. Therefore, OTA analyzed savings at 100 percent, 90 percent, and 80 percent of the USPS estimates.

Additional assumptions that apply to individual options are presented below.

Option A: Single-line OCR. OTA used the USPS cash flow estimate as the base line, and treated ZIP+4 usage as an uncertainty. During 1985-1988, the deployment period for single-line OCRs, OTA reduced USPS savings estimates by an amount proportional to reduced ZIP+4 usage. For example, if projected clerk/carrier savings in 1986 were based on an USPS-assumed ZIP+4 usage of 57 percent, but estimated by OTA to be 28 percent, the savings at the lower ZIP+4 level would be calculated at 28/57 = 49 percent of the USPS estimate. Beyond 1989, when the single-line OCRs would be fully installed and operational, OTA estimated savings by using the USPS curve of clerk/carrier savings versus ZIP+4 use.

Option B: Multi-line OCR with ZIP+4. Here, OTA assumed that for the next three years, 1985-1987, only Phase I single-line OCRs would be in operation, and the Phase I cost and savings estimates apply. The Phase I single-line OCRs would be converted to multi-line at an estimated conversion cost of $200,000 each, with the cost spread equally over three years, 1988-90, based on best available engineering judgment.

OTA estimates that the cost of Phase II multi-line OCRs would be $850,000 each (capital and expense), again based on engineering judgment, and compares to the USPS-estimated unit cost (capital and expense) of $750,120 for Phase II single-line OCRs. OTA assumed that the cost of multi-line OCRs would be spread over three years, 1988-90, which reflects a 3-year delay period (1985-87) for release-loan tests, competitive bidding, and contract award, and that the total number of OCRs would be the same, whether single- or multi-line. OTA assumed an additional multi-line OCR cost of $5 million per year for 3 years, 1985-87, to cover any further research and development and the release-loan testing of multi-line OCRs prior to procurement. The $5 million equates to about one-fifth of the 1983 USPS R&D budget. Otherwise, OTA assumed that Phase II equipment costs (bar code sorters, electronic ZIP retrofits, site preparation, address directory information update, and contingency) would be the same as for single-line (Option A).

OTA assumed that savings from the multi-line OCRs would phase in over the 1988-90 period and that full savings would begin in 1991, the year following full installation. Multi-line savings at a given level of ZIP+4 use are based on the curve of savings versus ZIP+4 use presented later. The curve is treated as an uncertainty, with pessimistic, median, and optimistic performance assumptions built in.

Option C: Multi-line OCR without ZIP+4. Option C is based on the same assumptions as Option B, except that the cost of the ZIP+4 rate incentive is dropped (since ZIP+4 would be terminated) and savings are estimated based on zero use of ZIP+4. For 1985-87, OTA assumed that savings would be the same as for the Phase I single-line OCRs with zero ZIP+4 use. For 1988-90, OTA assumed that one-third of the full savings benefit of Phase I single-line OCR conversion to multi-line would be realized in 1989, and two-thirds of the savings benefit in 1990. OTA assumed that Phase II multi-line OCR savings would phase in over 1988-90, and that full savings of converted Phase I OCRs and Phase II multi-line OCRs would begin in 1991.

Option D: Automatic Conversion. Here, OTA assumed that single-line OCRs would be purchased and installed on the same schedule as in Option A. Over the 1985-87 period, R&D and release-loan testing on single- to multi-line conversion would be conducted at $5 million per year. All single-line OCRs (Phase I and Phase II) would be converted to multi-line at a total cost of $31 million ($200,000 per conversion times 655 units) spread over 3 years, 1988-90. Clerk/carrier savings are assumed to be the same as option A savings through 1990, and the same as option B from 1991 on.

Option E: Hedge Conversion. In option E, OTA assumed conversion of single-line OCRs to multi-line only if ZIP+4 use is low at the end of 1987. If ZIP+4 use is at the high or median level, conversion would not take place and option E would be the same as option A except for a $5 million per year R&D and release-loan cost for 3 years, 1985-87. If ZIP+4 use is low, then conversion would take place and option E would be the same as option D.

Option F: Cancel. Here, OTA assumed that the Phase II OCR procurement would be cancelled, as would the ZIP+4 program and related rate incentives. The 252 single-line OGRs purchased in Phase I would be used to process 5-digit ZIP mail. OTA assumed that maintenance and spare parts costs would be the same, but that there would be no address directory information update cost. Clerk carrier savings for option F were assumed to be the same as with zero percent ZIP+4 use; that is, about 21 percent of the savings achievable at 90 percent ZIP+4 use, per USPS estimates.

OTA used option F as the baseline against which incremental cash flows of other options can be measured.

Option G: 50-50 Split Procurement. For option G, OTA assumed that the 252 Phase I single-line OCRs would be converted to multi-line in 1988-90 (as in options B, C, D); the Phase II procurement would be split, with 202 additional single-line OCRs purchased now, installed in 1985-87, and converted to multi-line in 1988-90 (same as option D except at one-half the number of single-line OCR units); and 201 multi-line OCRs would be purchased after release-loan testing and installed in 1988-90 (same as option B except at one-half the number of multi-line OCR units).

Thus, option G is an intermediate option between options B and D and would be expected to roughly split the difference between the two.

Option H: 90-10 Split Procurement. Option H is based on the same assumptions as option G except for the Phase II split: 363 (instead of 202) additional single-line OCRs would be purchased now, installed in 1985-87, and converted to multi-line in 1988-90; and 40 (instead of 201) multi-line OCRs would be purchased after release-loan testing and installed in 1988-90.

Discussion of Key Uncertainties

OTA gave explicit consideration to several uncertainties in the decision analysis. These included uncertainty about ZIP+4 usage, multi-line OCR performance, single- and multi-line savings rate, multi-line OCR cost, single- to multi-line conversion cost, multi-line ZIP+4 use, national directory feasibility and cost, single/multi-line OCR obsolescence, and multi-line OCR procurement delay.

The ZIP+4 usage, multi-line performance, and single/multi-line savings rate have proven to be the most controversial uncertainties. These are discussed first, followed by the less controversial uncertainties.

As shown in figure 5, the three most controversial uncertainties were included in many of the decision options. ZIP+4 usage was treated as an uncertainty in analysis of options A, B, D, E, and, by extension, G and H. Multi-line OCR performance was treated as an uncertainty in analysis of options B, C, D, E, G, and H. The single/multi-line savings rate was treated as an uncertainty in options A, B, C, D, E, G, and H.

ZIP+4 Usage. USPS has based its analysis on the assumption that 90 percent ZIP+4 usage will be achieved by the end of 1988. The 90 percent is calculated as a percentage of total machinable, metered first class letter mail of about 51 billion pieces. In order to achieve 90 percent by 1988, USPS assumed the following interim usage rates:

Figure 5

Uncertainties Included in Analysis of Decision Options

Decision Option	ZIP+4 Usage	Multi-Line OCR Performance	Single-/Multi-Line Savings Rate
A. Single-Line	Yes	No	Yes
B. Multi-Line with ZIP+4	Yes	Yes	Yes
C. Multi-Line Without ZIP+4	No	Yes	Yes
D. Automatic Conversion	Yes	Yes	Yes
E. Hedge Conversion	Yes	Yes	Yes
F. Cancel	No	No	No
G. 50-50 Split Procurement	Yes	Yes	Yes
H. 90-10 Split Procurement	Yes	Yes	Yes

Source: Office of Technology Assessment

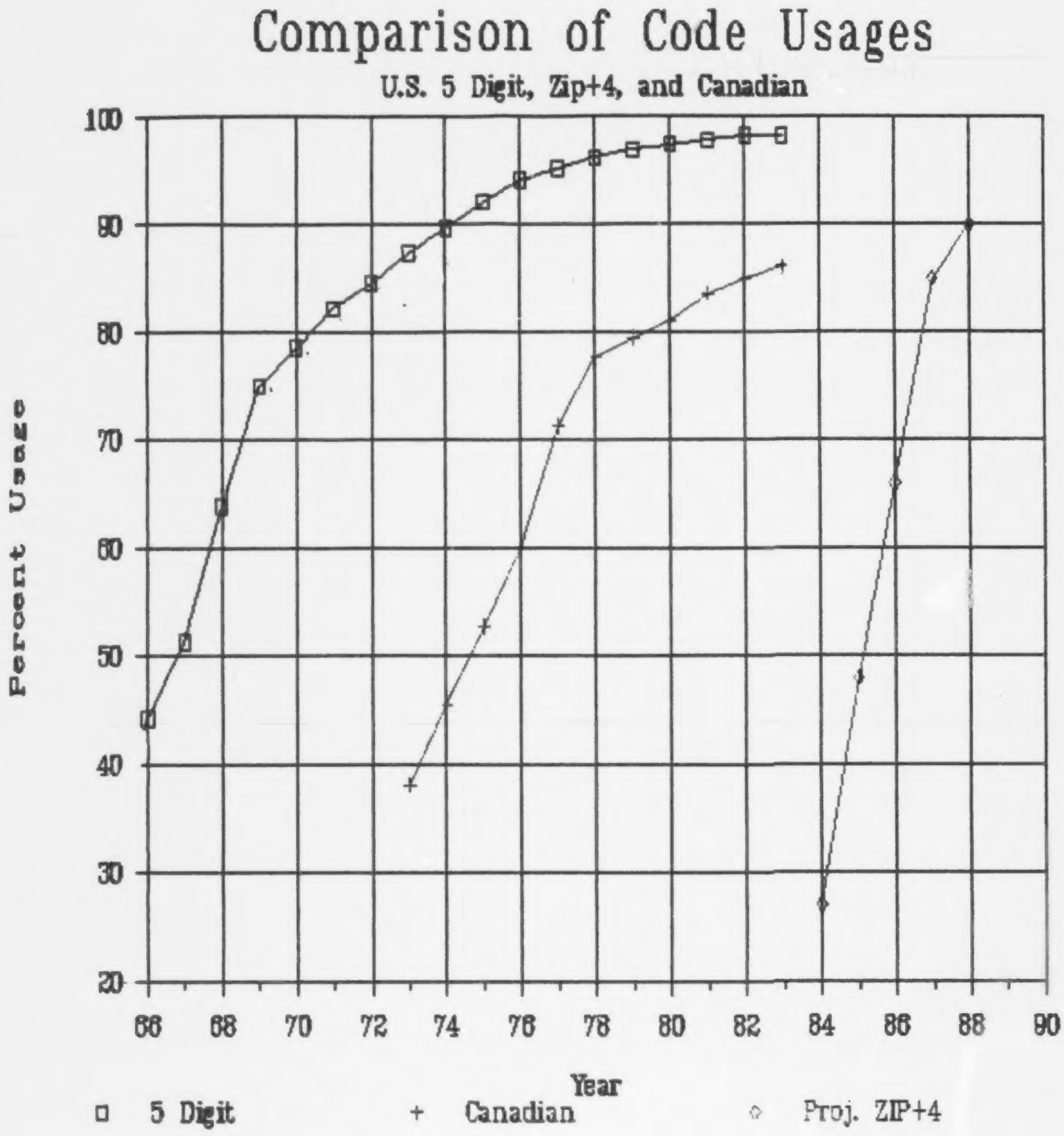
Year Ending	ZIP+4 Usage Rate	Pieces Of Mail
1984	27 percent	13.8 Billion
1985	48	24.5
1986	66	33.7
1987	85	43.4
1988	90	45.9

As of late May 1984, 59 mailers had actually converted their mailing address files to ZIP+4. Of these, 42 had qualified for ZIP+4 discounts and are expected to generate 401 million pieces on an anuual basis. Sixteen of the other 17 are expected to collectively generate 25 million pieces of non-qualifying ZIP+4 first class mail, and the seventeenth, 200 million pieces of third-class mail. Another 258 mailers had given USPS definite commitments to convert to ZIP+4 by December 1984. When fully converted, these 258 mailers are expected to generate a total of 2.1 billion pieces of first class mail annually.

Thus, at present, the projected actual volume of ZIP+4 mail (as a 1984 year-end volume and percentage of total machinable, metered first class mail) is about 2.73 billion pieces or about 19.8 percent of the original USPS projection. It is possible, of course, that additional mailers will decide to convert before the end of 1984. It is also possible that some of these already committed to convert will not actually do so.

As shown in figure 6, the original USPS projection of 90 percent ZIP+4 usage within 5 years is considerably more optimistic than actual experience with either the U.S. 5-digit ZIP code or the Canadian 6-digit postal code. The 5-digit ZIP took 12 years to reach 90 percent usage; after 5 years, the 5-digit usage level was about 51 percent. Thus, the USPS projection shows ZIP+4 reaching 90 percent about two and one-half times as fast (in 5 years rather than 12).

Figure 6



SOURCE: United States Postal Service

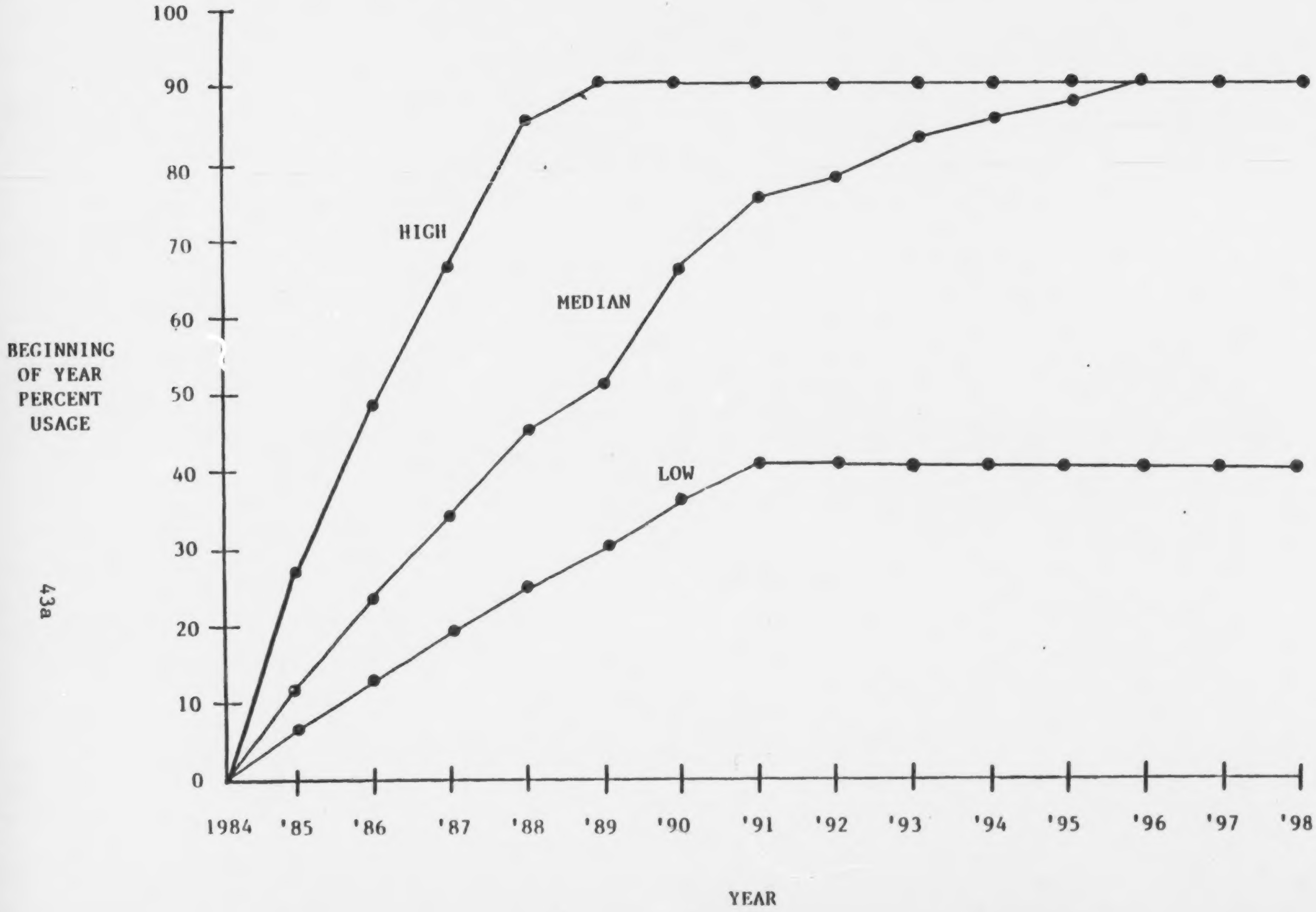
USPS justifies its projection on the grounds that "the technology used by mailers today is dramatically more sophisticated than that of the 1960's, when the 5-digit ZIP code was introduced. The widespread use of the 5-digit ZIP code, the proliferation of office automation and automated mailings, and the ZIP+4 incentive, all point to successful and accelerated acceptance of ZIP+4." (USPS, Jellison, 1984c). In 1983, GAO reviewed the one ZIP+4 market study cited by USPS (a 1982 survey conducted for USPS by R.H. Bruskin Associates). GAO expressed reservations about the study methodology (response rate too low, study universe not representative) and was unable to endorse the study results (GAO, 1983b, pp. iv-v, 31-36).

After reviewing all available evidence, OTA concluded that the USPS ZIP+4 projection should be considered optimistic, that an appropriate median estimate would be the 5-digit ZIP growth pattern, and that an appropriate pessimistic estimate would be a growth pattern similar to that of the USPS Electronic Computer Originated Mail Service (E-COM), where actual usage was about one-third of USPS projections. At the present time, the first year ZIP+4 usage could turn out to be even more pessimistic. The estimated 2.73 billion pieces of ZIP+4 first class mail at year end 1984 represents about 5.4 percent of the target mail base as compared to about 7 percent under the pessimistic scenario, 13 percent under the median, and 28 percent under the optimistic scenario.

OTA's ZIP+4 growth curves are shown in figure 7. OTA assumed that there is a 5 percent chance that actual ZIP+4 usage will equal or exceed the USPS projection (the high growth curve), a 50-50 chance that actual usage will be above or below the median growth curve (that is, it is equally likely that ZIP+4 usage will be above or below the 5-digit ZIP growth curve), and a 5 percent chance that ZIP+4 usage will be equal to or less than the low growth curve. At the present time, ZIP+4 growth is tracking a growth curve lower than the low curve in figure 7.

Figure 7

Growth in ZIP+4 Usage Rate



SOURCE: Office of Technology Assessment and United States Postal Service.

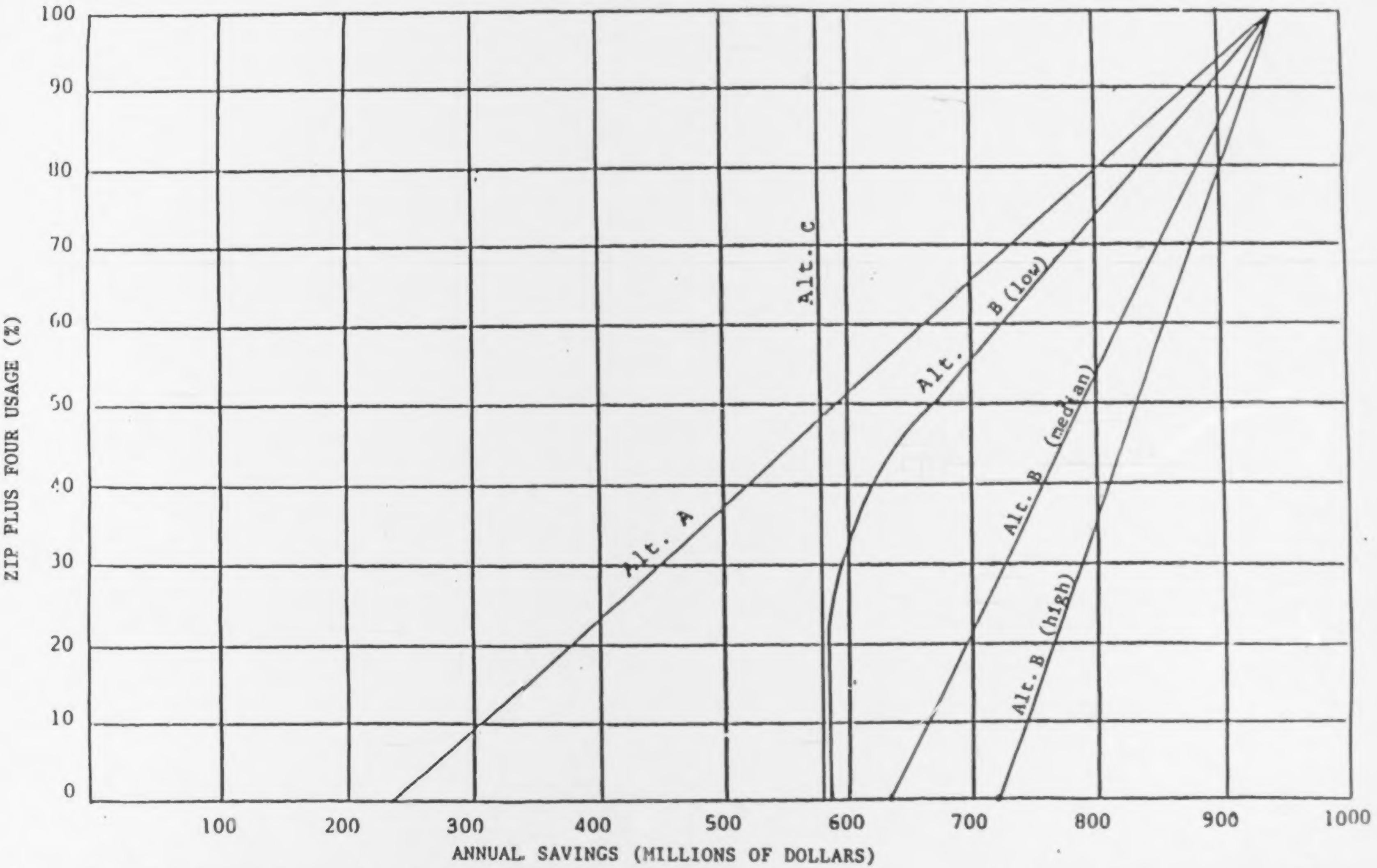
As a final note, GAO recently surveyed six business associations whose members mail large volumes of first class mail. Although not a representative sample, GAO found that while there is some interest in ZIP+4, businesses are still concerned about the cost of converting their address files (even with the current rate incentives) and whether the USPS presort program (and discounts) will end as a result of ZIP+4. In order to promote conversion, USPS is allowing "comingling" or mixing of up to 15 percent non-ZIP+4 mail in a ZIP+4 presort first class mailing until February 1, 1985, and up to 10 percent until October 1, 1985. As yet, however, there is little evidence that business mailers are giving ZIP+4 conversion a high priority.

Multi-line OCR performance. A major advantage of multi-line OCRs is the ability to read, code, and sort 5-digit ZIP mail to the 9-digit level. That is, unlike the single-line OCR, the multi-line OCR can process a significant percentage of 5-digit ZIP mail as if the ZIP+4 were being used but without actually requiring the ZIP+4 code to be on each letter. The multi-line OCR does this by matching the multi-line address information on the envelope with address and ZIP+4 information stored in a computerized address directory. Even though there is no ZIP+4 code on the envelope, when a match is made, the multi-line OCR prints the 9-digit bar code on the envelope.

At issue is not whether but how well the multi-line OCR can process 5-digit mail to the 9-digit level. USPS has estimated that the multi-line OCR can process 60 percent of 5-digit mail accepted by the OCR to the 9-digit level extra based on acceptance tests of the REI equipment. However, USPS notes that the 60 percent is "a projection that was not fully tested." Based on the 60 percent multi-line performance estimate (5-digit to 9-digit level) and more complete data available on single- and multi-line OCR processing of 9-digit (ZIP+4) mail, USPS developed a set of curves shown in figure 8 as alternatives A,

Figure 8

Estimates of 1989 Clerk/Carrier Savings



SOURCE: United States Postal Service (curves for Alternatives A, B(low), C); and Office of Technology Assessment (curves for Alternatives B (Median) and B (high).

Alt. A = Single-Line OCR With ZIP+4

Alt. B = Multi-Line OCR With ZIP+4

Alt. C = Multi-Line OCR Without ZIP+4

B [low], and C. These curves show the estimated annual clerk/carrier savings (in 1989 dollars) as a function of ZIP+4 usage for single-line OCRs and for multi-line OCRs with and without ZIP+4.

As discussed previously in the technical analysis, OTA concluded that the USPS estimate of 60 percent was pessimistic. OTA assumed that there was only a 5 percent chance that actual multi-line performance would be equal to or less than this low estimate. OTA concluded that a reasonable median estimate of performance was 65 percent, with a 50-50 chance that actual performance will be above or below, and that a reasonable high estimate was 75 percent, with a 5 percent chance that actual performance would equal or exceed this level.

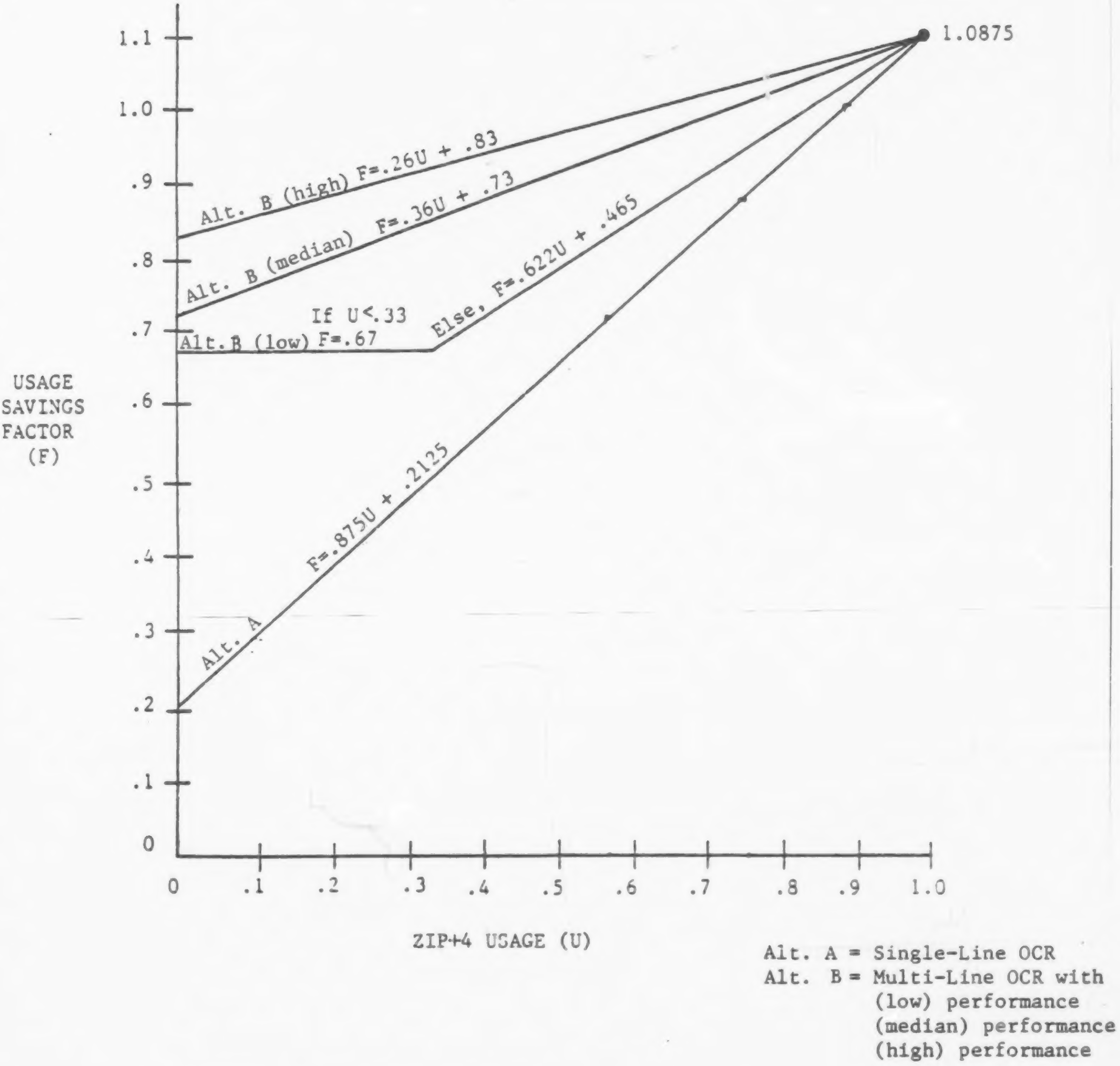
The multi-line OCR savings curves associated with low (60 percent), median (65 percent), and high (75 percent) performance are shown in figure 8. OTA used the USPS multi-line OCR savings curve as the low performance curve (marked as Alt. B [low] in figure 8), and developed new savings curves for median and high multi-line OCR performance (marked as Alt. B [median] and Alt B. [high], respectively, in figure 8). The x-intercepts of the three multi-line curves (savings at 0 percent ZIP+4 usage) correspond to about 67, 73, and 83 percent of the single-line OCR savings at 90 percent ZIP+4 usage. Thus, based on this set of curves, at zero percent ZIP+4 usage the annual savings estimates are approximately $580 million, $635 million, and $720 million for the three multi-line OCR alternatives, as compared to about $230 million for the single-line OCR alternative. (Note: The savings percentage at 0 percent ZIP+4 for Alt. B [low] was calculated by dividing $580 million, the multi-line savings at 0 percent ZIP+4 usage, by $870 million, the single-line savings at 90 percent ZIP+4 usage equals approximately 67 percent. Then, to estimate the multi-line savings percentage at 65 percent and 75 percent performance levels corresponding to Alt. B [median] and Alt. B [high], respectively, simple ratios were calculated: 65 percent/60 percent X 0.67 equals approximately 73 percent for Alt. B [median], and 75 percent/60 percent X 0.67 equals approximately 83 percent for Alt. B [high].)

As is evident from figure 8, the USPS multi-line with ZIP+4 curve (Alt. B. [low]) has an elbow in it, with no increase in the savings level occurring until ZIP+4 usage exceeds about 20 to 25 percent. USPS defends this "elbow" on the grounds that up to about 20 percent ZIP+4 usage, the read redundancy in the address and the ZIP+4 code negates any advantage from the multi-line OCR. In other words, USPS believes that the higher quality mail will be the first to use ZIP+4, and thus there will be no immediate benefit from multi-line processing. OTA was unable to establish a satisfactory engineering justification for this redundancy effect, and USPS was unable to provide a detailed explanation. Therefore, while OTA included the elbow in the USPS-estimated curve used as multi-line alternative B [low], OTA excluded the elbow for alternatives B [median] and B [high]. For these multi-line alternatives, OTA assumed a linear relationship between ZIP+4 usage and savings.

For modeling purposes, OTA converted the figure 8 curves into a set of normalized linear equations using ZIP+4 usage as the independent variable and usage savings factor as the dependent variable. A usage savings factor of 1.0 equates to 100 percent of the savings projected for the single-line OCR alternative at 90 percent ZIP+4 usage. The set of curves corresponding to the linear equations is shown in figure 9. The slope of the single-line OCR curve was adjusted slightly to be consistent with the ZIP+4 sensitivity analyses included in the 1984 USPS proposal to the Postal Board of Governors (savings factors of 1.0, 0.866, and 0.72 at ZIP+4 usage rates of 0.9, 0.76, and 0.57 [corresponds to 90 percent, 76 percent, and 57 percent ZIP+4 usage]).

Figure 9

Usage Savings Factors



SOURCE: Office of Technology Assessment

Single/multi-line savings rate. In addition to uncertainty over ZIP+4 usage and multi-line OCR performance, OTA included an uncertainty over the baseline level of clerk/carrier savings estimated by USPS. USPS asserts that their estimates are conservative, since the estimates "do not include additional savings from a reduction in operator scheme training, increased employee flexibility, error reduction, or the potential for encoding mail manually." USPS also points out that the savings estimates are based on machinable first-class mail only, and do not include savings from non-machinable first class mail or from semi-automated processing of ZIP+4 coded flats and parcels (for example, by using a wand reader or laser scanner).

On the other hand, the USPS savings estimates are vulnerable to lower than anticipated volume and/or higher than expected costs. Some large mailers may develop techniques for totally bypassing the OCRs, for example, by applying bar codes to outgoing letters at the same time addresses are printed. This would be an extension of presorting letters to the carrier route level, which is apparently already competing with postal automation. If a significant amount of machinable, easy to read (trayed and clean) first class mail is presorted and bypasses the OCRs, the OCRs would be left with a higher relative volume of lower quality mail with a lower OCR performance level to be expected. The net result could be a considerable decrease in OCR productivity and savings.

This downside potential is dramatized by comparing single-line OCR accept rates (percentage of mail fed to an OCR that is accepted by the machine) for different types of mail. USPS assumed, for example, an accept rate of 90 percent for presort first class mail but only 50 percent for collection box mail and 75 percent for bulk business mail. To the extent the OCR mail mix changes such that presort decreases relative to other mail types, then the overall OCR accept, productivity, and savings rates would decline, all other things being equal.

As to the possibility of higher than expected costs, the greatest vulnerability appears to be in the labor area, not in equipment. Although it is too early to have hard figures, it is possible that OCR maintenance labor costs will be higher than anticipated.

All factors considered, OTA concluded that the USPS baseline estimate of clerk/carrier savings was probably somewhat optimistic. OTA assumed that there is a 5 percent chance that the actual savings rate will equal or exceed 100 percent of the USPS baseline savings estimate, a 50-50 chance that the savings rate will be above or below 90 percent of the USPS baseline estimate, and a 5 percent chance that the actual rate will be equal to or less than 80 percent of the USPS estimate.

Multi-line OCR Cost. OTA noted some uncertainty about the purchase and maintenance costs of the multi-line OCR. Firm estimates are not possible in the absence of a competitive bidding on and operational experience with a large number of multi-line OCRs. USPS has estimated that multi-line OCRs would cost $200,000 more per unit to buy than single-line OCRs, or about $950,000 compared to the $750,000 (per single-line OCR unit (capital and expense) used in the USPS proposal to the Postal Board of Governors.

However, based on best available engineering judgment, OTA concluded that a $100,000 purchase cost difference is more realistic. Also, OTA conducted a sensitivity analysis on multi-line OCR purchase prices of $750,000, $850,000, and $950,000 and found that the impact on ROI/NPV was negligible, as will be discussed in a later section.

As for multi-line OCR maintenance cost, OTA concluded that the cost of updating the multi-line OCR address directory would probably be greater than updating the single-line OCR directory. USPS has very roughly estimated this additional maintenance cost at one work year per local directory per year (equivalent to three persons working for 4 months). Since 209 local directory updates would be needed (the number of cities projected to have OCRs), the additional yearly directory maintenance cost is estimated to be about $9.32 million (209 local directory updates times $44.6K per average work year). This amount is negligible (on the average one percent or less) compared to the total yearly multi-line savings, and therefore was excluded from further analyses.

Single- to multi-line conversion cost. In the absence of firm estimates, OTA assumed a conversion cost of $200,000 per unit, based on best available engineering judgment.

Multi-line ZIP+4 usage. USPS believes that use of multi-line OCRs would likely have a detrimental effect on mailer acceptance and use of ZIP+4. In other words, all other things being equal, USPS believes that ZIP+4 usage would be less for a multi-line OCR system than for a single-line OCR system.

While a few mailers have indicated that a USPS switch to multi-line OCRs would reduce the likelihood of converting to ZIP+4, the cost of conversion, level and stability of USPS ZIP+4 rate incentives, and relationship to USPS presort rate incentives appear to be much more important to mailers than the type of OCR equipment used by USPS. In sum, the available evidence suggests that mailers base their decisions about ZIP+4 use primarily on economic and financial factors and not on technological factors.

In addition, even the concerns stated by USPS would appear to be moot for options including an initial purchase of some or all of the Phase II single-line OCRs and subsequent conversion to multi-line capability. Since actual conversion would probably not begin for about 3 years, by that time it should be clear to what extent USPS projections of ZIP+4 usage with a single-line OCR system are being met.

National directory feasibility and cost. OTA originally included the cost of computerized national directories as a charge against multi-line OCR options, on the theory that national directories would be necessary for effective use of multi-line OCRs. However, upon further analysis, OTA concluded that national directories, while technically feasible, were not necessary, since the use of local directories in the origin and destination cities amounts to a de facto national directory. In addition, since a national directory has not yet been developed, estimating costs would be very difficult. As a result of these factors, the cost of national directories was removed from further consideration. (The cost of local directories was, of course, reflected in the estimates of multi-line OCR purchase price and single- to multi-line conversion price.)

Single/multi-line OCR obsolescence. OTA originally included as an uncertainty the obsolescence date for Phase II single-line OCR equipment (i.e., a 5 percent chance of becoming obsolete in 1994 or earlier). However, OTA concluded that the single-line OCRs could be upgraded, if necessary, to use new technologies and/or perform new or expanded functions. Therefore, the equipment obsolescence date was excluded as an uncertainty. All equipment was assumed to remain operational through 1998.

Multi-line OCR procurement delay. OTA originally assumed a 2-year delay in OCR procurement if USPS switched from single- to multi-line OCRs. Upon further analysis, OTA concluded that a 3-year delay was more reasonable, based on best available engineering judgment and USPS experience with single-line OCR release-loan testing, assuming no change in USPS procurement practices. USPS has likewise estimated a 3-year delay as more realistic, given the need to issue a new solicitation for release-loan testing of multi-line OCRs.

Results of Decision Analysis

Probabilistic cash flow models were developed for each option using the assumptions and uncertainties discussed previously. The models were then used to project estimated yearly cash flows, rate of return, and net present value for each decision option. (See appendices A and B for a detailed presentation of the models and cash flows for all options except options G and H, which were estimated by interpolation.)

The purpose of the modeling is to provide both absolute and comparative financial projections for each decision option. However, while the models generate numbers that appear to be very specific, the user of the results must understand that all projections are subject to some imprecision, especially in view of the large number of assumptions and uncertainties. But as long as these assumptions and uncertainties are treated consistently, the results should provide a valid basis for comparison among options.

Results of the decision analysis are presented below in the following order: rates of return, net present values, supplemental sensitivity analysis, and overall cash flows.

Rates of return. The cash flow models were used to estimate internal rates of return (ROIs) for each option under each condition of uncertainty. The ROIs were estimated on an incremental basis over option F (cancel), since OTA assumed that under any scenario, the Phase I single-line OCRs already purchased would be kept in service. Thus option F is in effect the baseline option. In essence, all ROIs are net of cash flows associated with Phase I single-line OCRs.

The estimated ROIs for all options under various conditions are shown in figure 10. Every option under all conditions modeled shows an ROI above the 15 percent threshold established by USPS. The lowest ROI is 20.6 percent, for option A (single-line OCR) under low ZIP+4 usage and a low savings rate. Only if ZIP+4 was even lower (e.g., peaked out at 20 percent usage instead of the 40 percent assumed in the low usage scenario) and/or the savings rate was even lower (e.g., 70 percent of USPS estimates instead of the 80 percent assumed in the low savings rate scenario) would the option A ROI drop below 15 percent.

The highest ROI is 84.6 percent, for option D (automatic conversion) under high ZIP+4 usage, multi-line performance rate, and savings rate. However, under these conditions options A (single-line OCR), E (hedge conversion), and H (90-10 split procurement) have only a slightly lower estimated ROI. The greatest difference between option D (automatic conversion) and option A (single-line OCR) occurs with low ZIP+4 usage and high multi-line OCR performance. Under these conditions, the option D ROI is anywhere from 33 to 50 percent higher than the option A ROI.

The relative ROI ranking of the various options as a function of ZIP+4 usage is as follows (excluding option F, cancel, which has a negative ROI):

Figure 10

Estimated Percentage Rates of Return for
Decision Options Under Various Conditions

				Multi-line OCR Performance Rate								
				Low			Median			High		
	Savings Rate			Savings Rate			Savings Rate			Savings Rate		
	L	M	H	L	M	H	L	M	H	L	M	H
High ZIP+4 Usage												
Option A	56.4	69.2	83.5									
Option B				45.6	58.2	74.7	46.4	59.0	75.5	46.7	59.3	75.7
Option D				56.6	69.6	84.2	57.1	70.0	84.5	57.3	70.2	84.6
Option E*	56.4	69.2	83.5									
Option G**				51.1	63.9	79.6	51.8	64.5	80.0	52.0	64.8	80.2
Option H**				55.5	68.5	83.3	56.0	68.9	83.6	56.2	69.1	83.7
Median ZIP+4 Usage												
Option A	37.4	43.6	49.7									
Option B				33.7	39.7	45.7	35.0	41.0	47.0	35.4	41.5	47.5
Option D				37.8	44.1	50.3	38.8	45.1	51.2	39.2	45.4	51.5
Option E*	37.4	43.6	49.7									
Option G**				35.8	41.9	48.0	36.9	43.1	49.1	37.3	43.5	49.5
Option H**				37.4	43.7	49.8	38.4	44.7	50.8	38.8	44.7	51.1
Low ZIP+4 Usage												
Option A	20.6	25.3	29.7									
Option B				22.3	26.7	30.8	27.8	32.1	36.1	29.5	33.8	37.8
Option D				25.3	29.8	34.0	29.7	34.0	38.1	31.1	35.4	39.4
Option E*				25.3	29.8	34.0	29.7	34.0	38.1	31.1	35.4	39.4
Option G**				23.8	28.3	32.4	28.8	33.1	37.1	30.3	34.6	38.6
Option H**				25.0	29.5	33.7	29.5	33.8	37.9	30.9	35.2	39.2
Zero ZIP+4 Usage												
Option C				32.3	37.8	43.2	34.4	39.9	45.3	37.6	43.1	48.5

---

* ROIs for Option E are the same as Option A at high and median ZIP+4 usage and the same as Option D at low usage.

** ROIs for Options G and H were calculated by interpolation from Options B and D (i.e., Option G was assumed to have an ROI that split the difference between Options B and D).

NOTE: All ROIs are incremental over Option F (cancel)

Source: Office of Technology Assessment

High and Median ZIP+4 Usage

Option D	Highest ROI
Option H	
Options A and E	
Option G	
Option B	Lowest ROI

Low ZIP+4 Usage

Option C	Highest ROI
Options D and E	
Option H	
Option G	
Option B	
Option A	Lowest ROI

Thus, at high or median ZIP+4 usage, options D and H have the highest ROIs. And at low ZIP+4 usage, options C, D, E, and H have the highest ROIs.

Net present values. Use of ROIs for decisionmaking has a serious limitation. When more than one option clears the hurdle rate (that is, has more than the minimum required ROI, in this case 15 percent), the ROI itself gives no indication of the cash flow differences of the various options as a basis for comparing the options. An alternative to ROI frequently used in capital investment decisionmaking is net present value (NPV). NPV discounts the cash flows of each option at the hurdle or threshold rate, in this study 15 percent.

Estimated NPVs for all options under all conditions (except option F, cancel, which has a negligible NPV of $232,199) are shown in figure 11. The relative ranking of the options based on NPV is the same as the ranking based on ROI, except for option C. However, there is a significant difference in the absolute rankings when using NPV.

Figure 11

Estimated Net Present Values (in billions of dollars)
for Decision Options Under Various Conditions

				Multi-line OCR Performance Rate								
				Low			Median			High		
	Savings Rate			Savings Rate			Savings Rate			Savings Rate		
	L	M	H	L	M	H	L	M	H	L	M	H
High ZIP+4 Usage												
Option A	1.50	1.91	2.33									
Option B				1.07	1.42	1.77	1.12	1.48	1.84	1.14	1.50	1.86
Option D				1.51	1.93	2.35	1.57	1.99	2.42	1.59	2.01	2.44
Option E*	1.50	1.91	2.33									
Option G**				1.29	1.68	2.06	1.35	1.74	2.13	1.36	1.76	2.15
Option H**				1.47	1.88	2.29	1.53	1.94	2.36	1.55	1.96	2.38
Median ZIP+4 Usage												
Option A	1.05	1.38	1.71									
Option B				0.82	1.12	1.41	0.90	1.21	1.51	0.93	1.24	1.55
Option D				1.09	1.43	1.77	1.17	1.52	1.87	1.19	1.55	1.90
Option E*	1.05	1.38	1.71									
Option G**				0.96	1.28	1.59	1.04	1.37	1.69	1.06	1.40	1.73
Option H**				1.06	1.40	1.73	1.14	1.49	1.83	1.16	1.52	1.87
Low ZIP+4 Usage												
Option A	0.21	0.41	0.61									
Option B				0.30	0.50	0.70	0.59	0.83	1.07	0.70	0.95	1.20
Option D				0.46	0.70	0.93	0.75	1.03	1.30	0.86	1.15	1.43
Option E*				0.46	0.70	0.93	0.75	1.03	1.30	0.86	1.15	1.43
Option G**				0.38	0.60	0.82	0.67	0.93	1.17	0.78	1.05	1.32
Option H**				0.44	0.68	0.91	0.73	1.01	1.28	0.84	1.13	1.41
Zero ZIP+4 Usage												
Option C				0.58	0.78	0.99	0.69	0.91	1.13	0.87	1.11	1.36

---

* NPVs for Option E are the same as Option A at high and median ZIP+4 use and the same as Option D at low usage.

** NPVs for options G and H were calculated by interpolation from Options B and D (i.e., Option G was assumed to have a NPV that split the difference between Options B and D).

NOTE: All NPVs are incremental over Option F (cancel).

Source: Office of Technology Assessment

Under conditions of high and medium ZIP+4 usage, high savings, and high multi-line performance, option D (automatic conversion) has about a 5 percent and 11 percent higher NPV, respectively, than option A (single-line OCR). At low ZIP+4 usage, all other things being equal, the option D advantage increases to a substantial 134 percent or about $820 million in NPV. At a low savings rate (along with low ZIP+4 usage and high multi-line performance), the relative advantage of option D over A increases further to about 310 percent although the absolute advantage decreases to about $650 million in NPV. Even at low multi-line performance, with low ZIP+4 usage option D has a 53 to 119 percent relative advantage in NPV and a $320 to 250 million absolute advantage in NPV, at a high and low savings rate, respectively. Option H (90-10 split procurement) also has a higher NPV than option A under almost all conditions. Option G (50-50 split procurement) has a significant although somewhat smaller advantage over option A at low ZIP+4 usage.

The net NPV advantage or disadvantage of options D, G, and H compared to option A is shown in figure 12 for various conditions. Relative as well as absolute comparisons are included for low ZIP+4 usage. The results clearly show that options D and H have a marginally higher NPV at high and medium ZIP+4 usage under all conditions and a substantially higher NPV at low ZIP+4 usage. On the other hand, option G has a marginally lower NPV than option A at high ZIP+4 usage and median ZIP+4 usage with low or median multi-line performance, a marginally higher NPV at median ZIP+4 usage and high ZIP+4 performance, and a substantially higher NPV under all low ZIP+4 conditions.

Another way to present these results is shown in figure 13. Here, the 80 percent credible values are shown for each option along with the overall net present value for

Figure 12

Comparison of Net Present Values (in percentages and billions of dollars) of Options D, G, and H with Option A

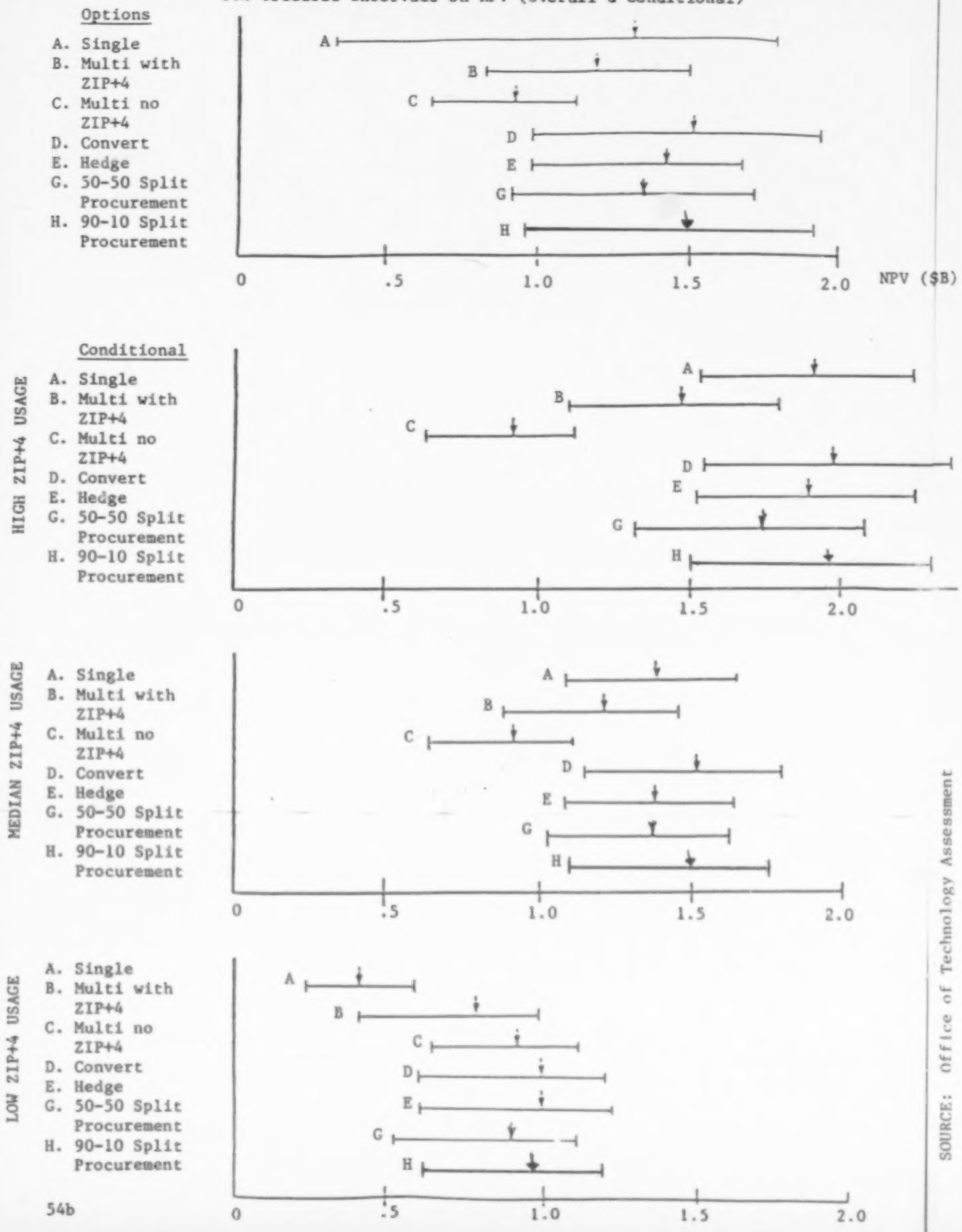
	Multi-line OCR Performance Rate								
	Low			Median			High		
	Savings Rate			Savings Rate			Savings Rate		
	Low	Med.	High	Low	Med.	High	Low	Med.	High
High ZIP+4 Usage									
Option D ($)	0.01	0.02	0.02	0.07	0.08	0.09	0.09	0.10	0.11
Option G ($)	-0.21	-0.23	-0.27	-0.15	-0.17	-0.20	-0.13	-0.15	-0.18
Option H ($)	-0.03	-0.03	-0.04	0.03	0.03	0.03	0.05	0.05	0.05
Median ZIP+4 Usage									
Option D ($)	0.04	0.05	0.06	0.12	0.14	0.16	0.14	0.17	0.19
Option G ($)	-0.09	-0.10	-0.12	-0.01	-0.01	-0.01	0.01	0.02	0.03
Option H ($)	0.01	0.02	0.02	0.09	0.11	0.12	0.11	0.14	0.16
Low ZIP+4 Usage									
Option D (%)	119	71	53	257	151	113	310	181	134
($)	0.25	0.29	0.32	0.54	0.62	0.69	0.65	0.74	0.82
Option G (%)	81	46	34	209	127	92	271	156	116
($)	0.17	0.19	0.21	0.46	0.52	0.56	0.57	0.64	0.71
Option H (%)	110	66	49	248	146	105	300	176	131
($)	0.23	0.27	0.30	0.52	0.60	0.67	0.63	0.72	0.80

Notes:
Option D = Automatic conversion.
Option G = 50-50 Split procurement.
Option H = 90-10 Split procurement.
All dollar figures in billions and are net of Option A NPV from Figure 11.
All NPVs are incremental over Option F (cancel).

Source: Office of Technology Assessment

Figure 13

80% Credible Intervals on NPV (Overall & Conditional)



SOURCE: Office of Technology Assessment

each option. The 80 percent credible interval means that there is a 10 percent chance of NPV being above the largest value and a 10 percent chance of NPV being below the smallest value. The NPVs and credible intervals are shown overall and conditional on ZIP+4 usage.

Figure 13 shows, in effect, the ranking of the options by expected net present value and the range of uncertainty in NPV associated with each option, both overall and conditional on ZIP+4 use. The ranking of the options by expected NPV is summarized below:

Overall	NPV Rank
Option D	1 highest
H	2
E	3
G	4
A	5
B	6
C	7 lowest
Low ZIP+4 Usage	
Option D	1 highest
E	2 tie
H	3
C	4
G	5
B	6
A	7 lowest

Thus, option D (automatic conversion) ranks first in NPV both overall and with low ZIP+4 usage. Option H (90-10 split procurement) ranks second in NPV overall and third with low ZIP+4 usage. Option E (hedge conversion) ranks third in NPV overall and ties for first with low ZIP+4 usage. Options G (50-50 split procurement) and A (single-line OCR) rank almost identically in overall NPV. Option B (multi-line with ZIP+4) ranks relatively low (6th) in NPV, both overall and with low ZIP+4 usage. Option C (multi-line without ZIP+4) ranks the lowest in overall NPV, but somewhat higher (4th) in NPV with low ZIP+4 usage. Option A (single-line) ranks the lowest in NPV with low ZIP+4 usage.

The dominance of option D (automatic conversion) can also be illustrated by plotting the cumulative probability distributions of NPV for each option. As shown in figure 14, for any value of NPV (incremental over option F [cancel]), the probability is greatest for option D. For example, for an NPV of $1 billion, the probability is about 0.9 or 90 percent that option D will exceed that NPV (cumulative probability of about 0.1), about 0.75 that option A will exceed, about 0.7 that option B will exceed, and only 0.5 (or 50 percent) that option C will exceed $1 billion.

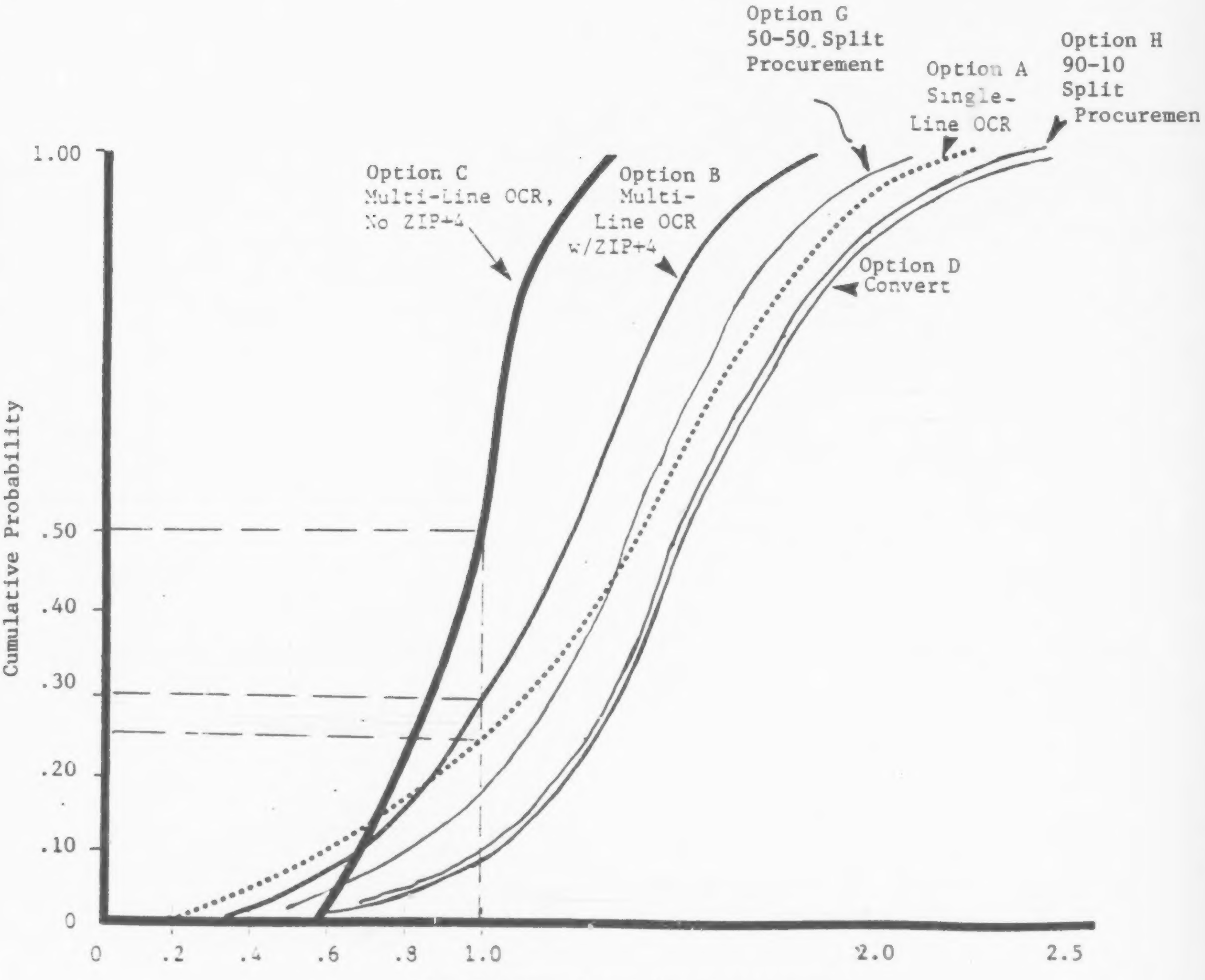
Because option D dominants all other options under all conditions of uncertainty, option D is stochastically dominant.

Supplemental sensitivity analysis. The basic models built in three uncertainties (ZIP+4 usage, savings rate, multi-line performance rate). A supplemental analysis was conducted to check the sensitivity of NPV results to changes in the purchase price of the multi-line OCR or the number of multi-line OCR units.

The results, summarized in figure 15, showed that an increase in multi-line OCR purchase price from $850,000 to $970,000 would have very little effect on NPV. The effect would be to reduce NPV by about $0.02 and 0.03 billion. Likewise, an increase in the number of multi-line OCR units from 403 to 439 (as estimated by GAO to be required if the entire Phase II procurement was switched from single- to multi-line OCRs) would cost about an additional $34.9 million (41 units x 850,000/unit), which is less than the $40.3 million cost of a $120,000 price increase for 403 machines. Therefore, the effect on NPV again would be very little.

Figure 14

Cumulative Probability Distributions
of Net Present Value (Smoothed)



Source: Office of Technology Assessment

Figure 15

Sensitivity of Net Present Value to Multi-line OCR Purchase Cost

			NPV* with Different Multi-line OCR Unit Costs ($ in billions)		
ZIP+4 Use	Multi-line Performance Rate	Savings Rate	@ $750K	@ $850K	@ $970K
HIGH	High	High	1.88	1.86	1.84
		Median	1.52	1.50	1.48
		Low	1.16	1.14	1.12
	Median	High	1.86	1.84	1.81
		Median	1.50	1.48	1.46
		Low	1.14	1.12	1.10
	Low	High	1.79	1.77	1.75
		Median	1.44	1.42	1.40
		Low	1.09	1.07	1.04
MEDIAN	High	High	1.57	1.55	1.52
		Median	1.26	1.24	1.21
		Low	.95	.93	.90
	Median	High	1.53	1.51	1.49
		Median	1.23	1.21	1.18
		Low	.92	.90	.88
	Low	High	1.43	1.41	1.39
		Median	1.14	1.12	1.09
		Low	.84	.82	.80
LOW	High	High	1.22	1.20	1.18
		Median	.97	.95	.93
		Low	.72	.70	.68
	Median	High	1.09	1.07	1.04
		Median	.85	.83	.80
		Low	.61	.59	.57
	Low	High	.72	.70	.68
		Median	.52	.50	.47
		Low	.32	.30	.27

---

* NPV for option B (multi-line OCR with ZIP+4) adjusted to reflect different purchase costs.

Source: Office of Technology Assessment

In sum, neither a modest increase in price per unit for the multi-line OCRs or in the total number of units would significantly change the NPVs.

Overall and selected year cash flows. Net present value is the best basis for comparative quantitative evaluation of the decision options. However, the actual undiscounted net cash flows over the 13 year payback period (1985-98) can provide another dimension to the evaluation.

Comparative net cash flows for selected options and conditions are shown in figure 16. Option A (single-line) is estimated to show positive cash flows of $8.8, $8.24, and $3.57 billion at high, medium, and low ZIP+4 usage. At high ZIP+4 usage, option B (multi-line with ZIP+4) is somewhat lower at $8.14 billion, options D (automatic conversion) and H (90-10 split procurement) somewhat higher at $9.36 billion and 9.24 billion respectively, and option G (50-50 split procurement) about the same at $8.75 billion. The comparisons between options change relatively little at median ZIP+4 usage.

However, at low ZIP+4 usage there is a substantial difference in net cash flows. Option A (single-line) shows a net cash flow of $3.57 billion. But, depending on the multi-line OCR performance rate, options D (automatic conversion) and H (90-10 split procurement) show a net cash flow of $5 to 7.2 billion, or about $1.4 to 3.6 billion greater than option A. Option G (50-50 split procurement) shows about $1.1 to 3.3 billion greater cash flow than option A, and option B (multi-line with ZIP+4) shows about $0.8 to 3.0 billion greater cash flow than option A.

A comparison of yearly cash flows gives similar results. Yearly cash flows for selected options and conditions are shown in figure 17, for the years 1994-98. By this time, all equipment will presumably have been installed (or converted) and up and running

Figure 16

Comparative Net Cash Flows,
Selected Options and Conditions,
1985-1998 (in $ billions)

	Option A (Single-line)	Option B (Multi-line with ZIP+4)	Option D (Automatic Conversion)	Option G* (50-50 Split Procurement)	Option H* (90-10 Split Procurement)
High ZIP+4 Usage High Savings Rate High Multi-line Performance					
Net Cash Flow	+$8.80	+$8.14	$9.36	+$8.75	+$9.24
Compared to Option A		-0.66	+0.56	-0.05	+0.44
Median ZIP+4 Usage High Savings Rate High Multi-line Performance					
Net Cash Flow	+$8.24	+$7.59	+$9.03	+$8.31	+$8.89
Compared to Option A		-0.65	+0.79	+0.07	+0.65
Low ZIP+4 Usage High Savings Rate High Multi-line Performance					
Net Cash Flow	+$3.57	+$6.57	+$7.19	+$6.88	+$7.13
Compared to Option A		+3.01	+3.62	+3.31	+3.56
Low ZIP+4 Usage High Savings Rate Median Multi-line Performance					
Net Cash Flow	+$3.57	+$5.98	+$6.59	+$6.29	+$6.54
Compared to Option A		+2.41	+3.02	+2.72	+2.97
Low ZIP+4 Usage High Savings Rate Low Multi-line Performance					
Net Cash Flow	+$3.57	+$4.38	+$5.00	+$4.69	+$4.94
Compared to Option A		+0.82	+1.43	+1.12	+1.37

---

* Options G and H calculated by interpolating between Options B and D.

NOTE: All net cash flow figures in undiscounted dollars.

SOURCE: Office of Technology Assessment

Figure 17

Comparative Net Cash Flows,
Selected Options, Conditions, and Years
(in $ billions)

		Option A (Single-line)	Options B (Multi-line) D (Automatic Conversion) G (50-50 Split Procurement) H (90-10 Split Procurement)	Options B, G, D, H Compared to Option A
High ZIP+4 Usage				
High Savings Rate				
High Multi-line Performance				
Net Cash Flow	1994	$0.87	$0.94	$0.07
	1995	0.94	1.02	0.08
	1996	1.02	1.11	0.09
	1997	1.11	1.20	0.09
	1998	1.20	1.30	0.10
Low ZIP+4 Usage				
High Savings Rate				
High Multi-line Performance				
Net Cash Flow	1994	0.43	0.87	0.44
	1995	0.46	0.93	0.47
	1996	0.50	1.01	0.51
	1997	0.54	1.09	0.55
	1998	0.59	1.17	0.58
Low ZIP+4 Usage				
High Savings Rate				
Median Multi-line Performance				
Net Cash Flow	1994	0.43	0.80	0.37
	1995	0.46	0.86	0.40
	1996	0.50	0.93	0.43
	1997	0.54	1.00	0.47
	1998	0.59	1.08	0.49
Low ZIP+4 Usage				
High Savings Rate				
Low Multi-line Performance				
Net Cash Flow	1994	0.43	0.61	0.18
	1995	0.46	0.66	0.20
	1996	0.50	0.71	0.21
	1997	0.54	0.77	0.23
	1998	0.59	0.83	0.24

Source: Office of Technology Assessment

at optimal performance. Options B, D, G, and H will by that time look exactly the same -- all multi-line OCRs. The single-line OCRs procured under options D, G, and H will have been converted to multi-line capability. Option A will continue to be solely single-line OCRs.

With high ZIP+4 usage, option A shows an annual net cash flow of about $870 million to $1.2 billion from 1994 to 1998. Options B, D, G, and H show almost identical annual cash flows, only slightly higher by about $70 to $100 million per year. However, at low ZIP+4 usage, the differences again become substantial. With high multi-line performance, options B, D, G, and H show between $440 and 580 million per year additional net cash flow compared to option A, from 1994 to 1998. With median multi-line performance, the advantage of options B, D, G, and H ranges from $370 to 490 million per year. And even at low multi-line performance, the advantage over option A, while reduced, is still significant at $180 to 240 million per year.

Appendix A: Modeling Methodology

The basic methodology employed was to develop probabilistic cash flow models for each of the decision options (except for the split procurement options, which were analyzed by interpolating from results of other options).

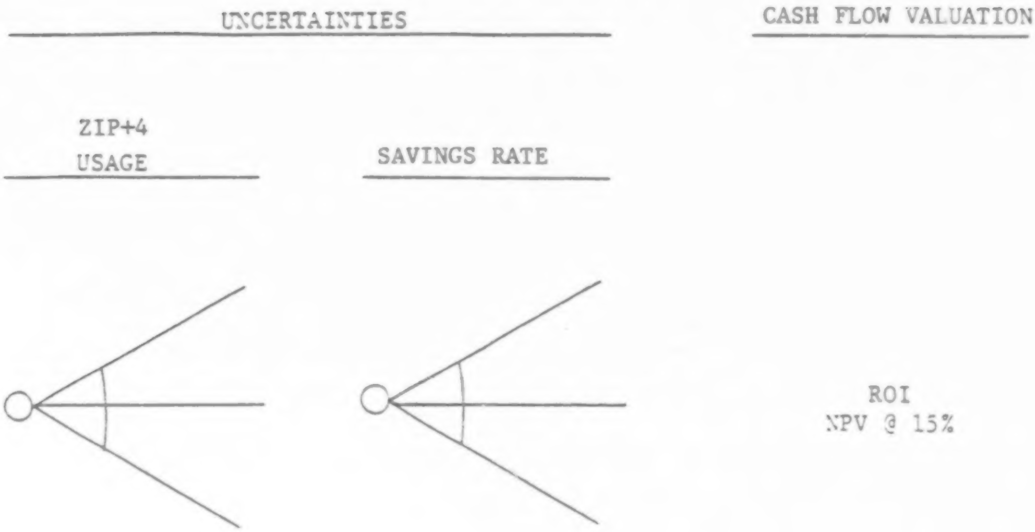
A decision tree was developed for each option. The tree included the uncertainties discussed previously, as applicable to each specific option, and a cash flow valuation measured by rate of return (ROI) and net present value (NPV) discounted at 15 percent, as illustrated conceptually in figure A-1. The uncertainties (i.e., ZIP+4 usage, savings rate, multi-line OCR performance rate) were treated as continuous random variables. The continuous random distributions were approximated by the Pearson-Tukey approximation which uses values of the variable at three discrete points: the 5 , 50, and 95 percentiles. Pearson-Tukey assigns probabilities of 0.185, 0.63, and 0.185 to these three percentiles, as shown in figure A-2.

Simplified schematic models for options A, B, C, D, and E are shown in figures A-3 through A-7. The full models are shown in appendix B.

The models were run on an IBM Personal Computer using Lotus 1-2-3 and proprietary software.

Figure A-1

Probabilistic Cash Flow Model
(Illustrated for Option A: Single-Line OCR)

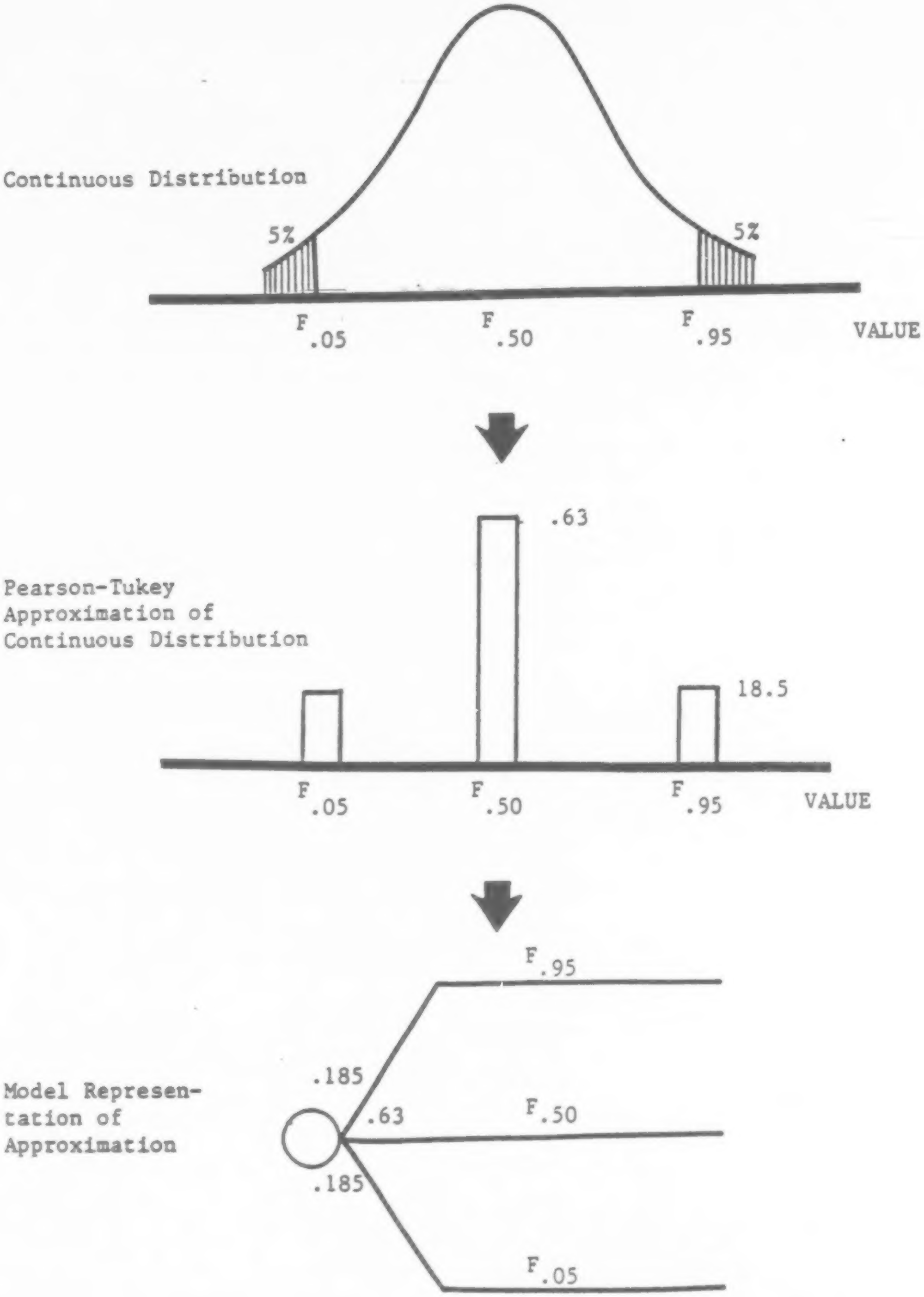

UNCERTAINTIES
CASH FLOW VALUATION
ZIP+4 USAGE
SAVINGS RATE
ROI
NPV @ 15%

The uncertainties are continuous random variables. A simplified representation of these distributions is used in the analysis (as explained in figure A-2.

Source: Office of Technology Assessment

Figure A-2

Simplified Representation of Continuous
Probability Distribution

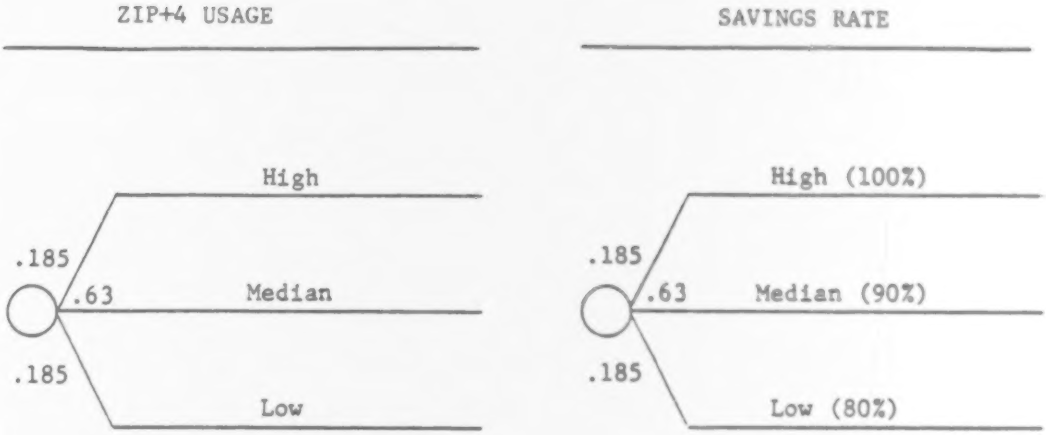

Continuous Distribution
5%
5%
F.05
F.50
F.95
VALUE
.63
Pearson-Tukey
Approximation of
Continuous Distribution
18.5
F.05
F.50
F.95
VALUE
F.95
Model Represen-
tation of
Approximation
.185
.63
F.50
.185
F.05

This representation is a Pearson-Tukey approximation. It was chosen because it provides an excellent approximation to a wide range of continuous probability distributions, as explained in Keefer and Bodily (1983).

Source: Office of Technology Assessment

Figure A-3

Simplified Schematic Model for
Option A: Single-Line OCR

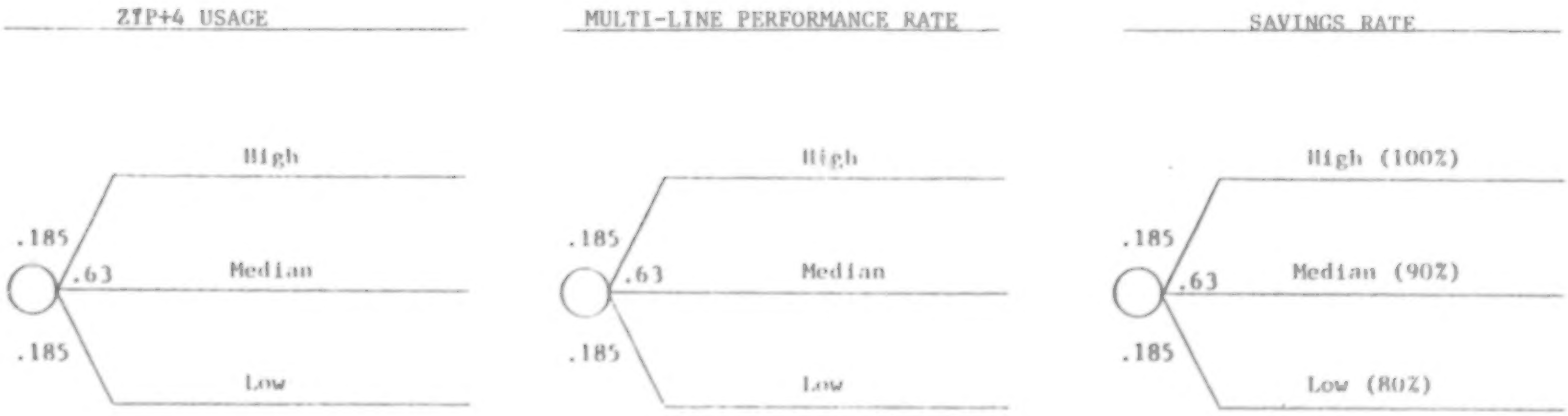

ZIP+4 USAGE
High
.185
.63
Median
.185
Low
SAVINGS RATE
High (100%)
.185
.63
Median (90%)
.185
Low (80%)

(See figures 7, 8, 9)

SOURCE: Office of Technology Assessment

Figure A-4

Simplified Schematic Model for
Option B: Multi-Line OCR with ZIP+4


ZIP+4 USAGE
High
.185
.63
Median
.185
Low
MULTI-LINE PERFORMANCE RATE
High
.185
.63
Median
.185
Low
SAVINGS RATE
High (100%)
.185
.63
Median (90%)
.185
Low (80%)

Same as with
single-line OCR

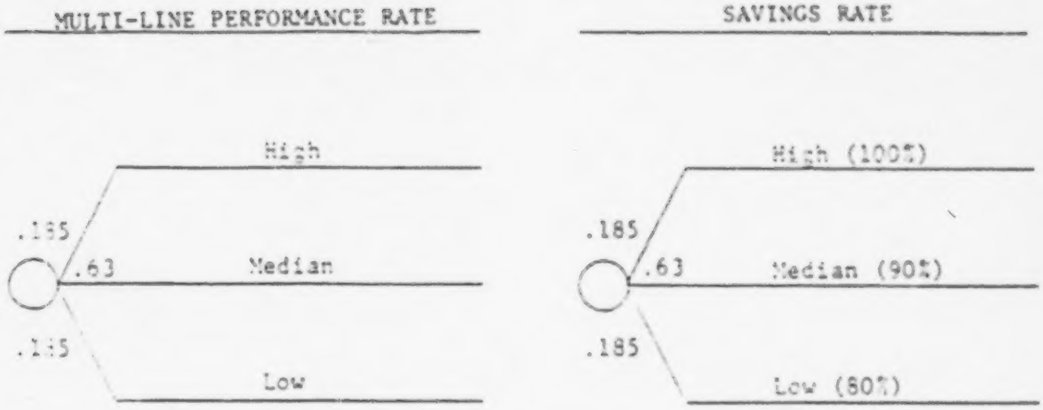
(See figures 8 and 9)

Same as with
single-line OCR

SOURCE: Office of Technology Assessment.

Figure A-5

Simplified Schematic Model
for Option C: Multi-Line OCR Without ZIP+4


MULTI-LINE PERFORMANCE RATE
High
.185
.63
Median
.185
Low
SAVINGS RATE
High (100%)
.185
.63
Median (90%)
.185
Low (80%)

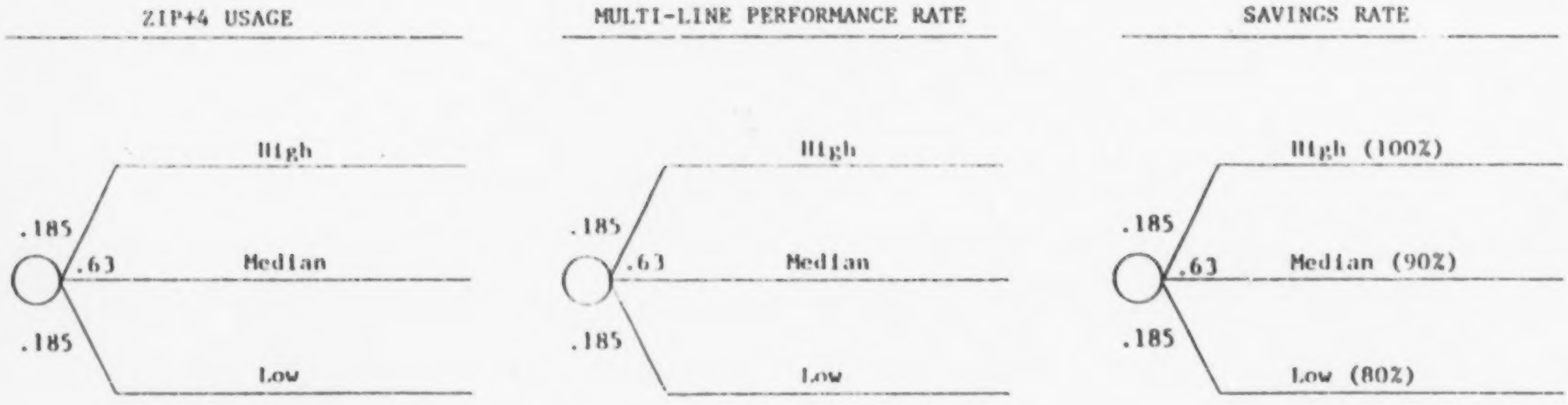
(See figures 8 and 9 at 0% ZIP+4 usage)

Same as for all other options

SOURCE: Office of Technology Assessment.

Figure A-6

Simplified Schematic Model for
Option D: Automatic Conversion


ZIP+4 USAGE
.185
.63
.185
High
Median
Low
MULTI-LINE PERFORMANCE RATE
.185
.63
.185
High
Median
Low
SAVINGS RATE
.185
.63
.185
High (100%)
Median (90%)
Low (80%)

Same as for Single-Line or Multi-Line with ZIP+4

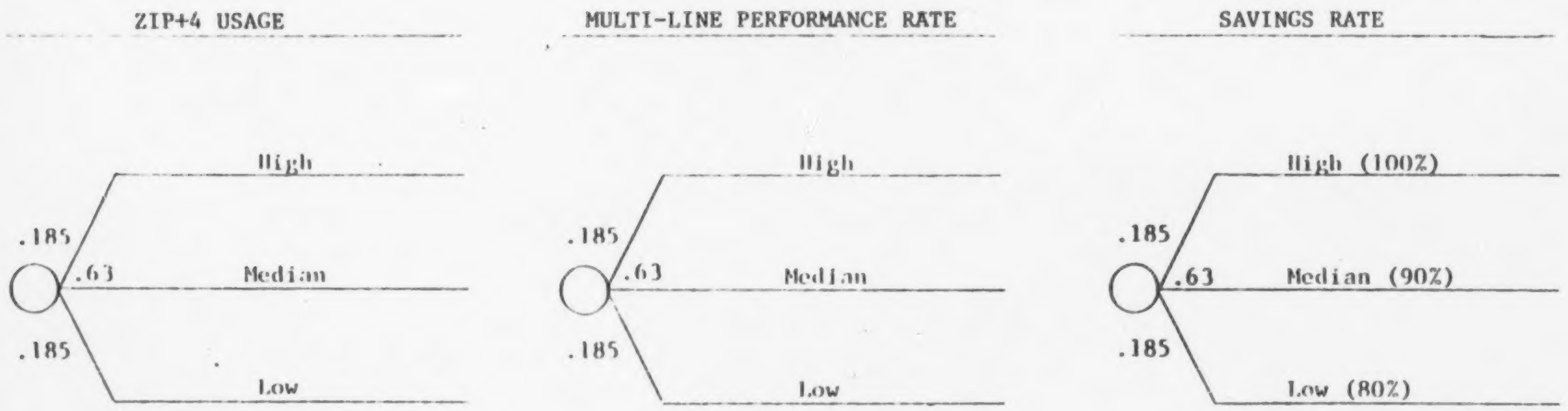
Same as for Multi-Line with ZIP+4

Same as for all the options

SOURCE: Office of Technology Assessment.

Figure A-7

Simplified Schematic Model for
Option E: Hedge Conversion


ZIP+4 USAGE
High
.185
.63
Median
.185
Low
MULTI-LINE PERFORMANCE RATE
High
.185
.63
Median
.185
Low
SAVINGS RATE
High (100%)
.185
.63
Median (90%)
.185
Low (80%)

Same as all other options with ZIP+4

Same as for Multi-Line with ZIP+4 (applies only if usage is low)

Same as all other options

SOURCE: Office of Technology Assessment.

Appendix B: Detailed Cash Flow Models and Results

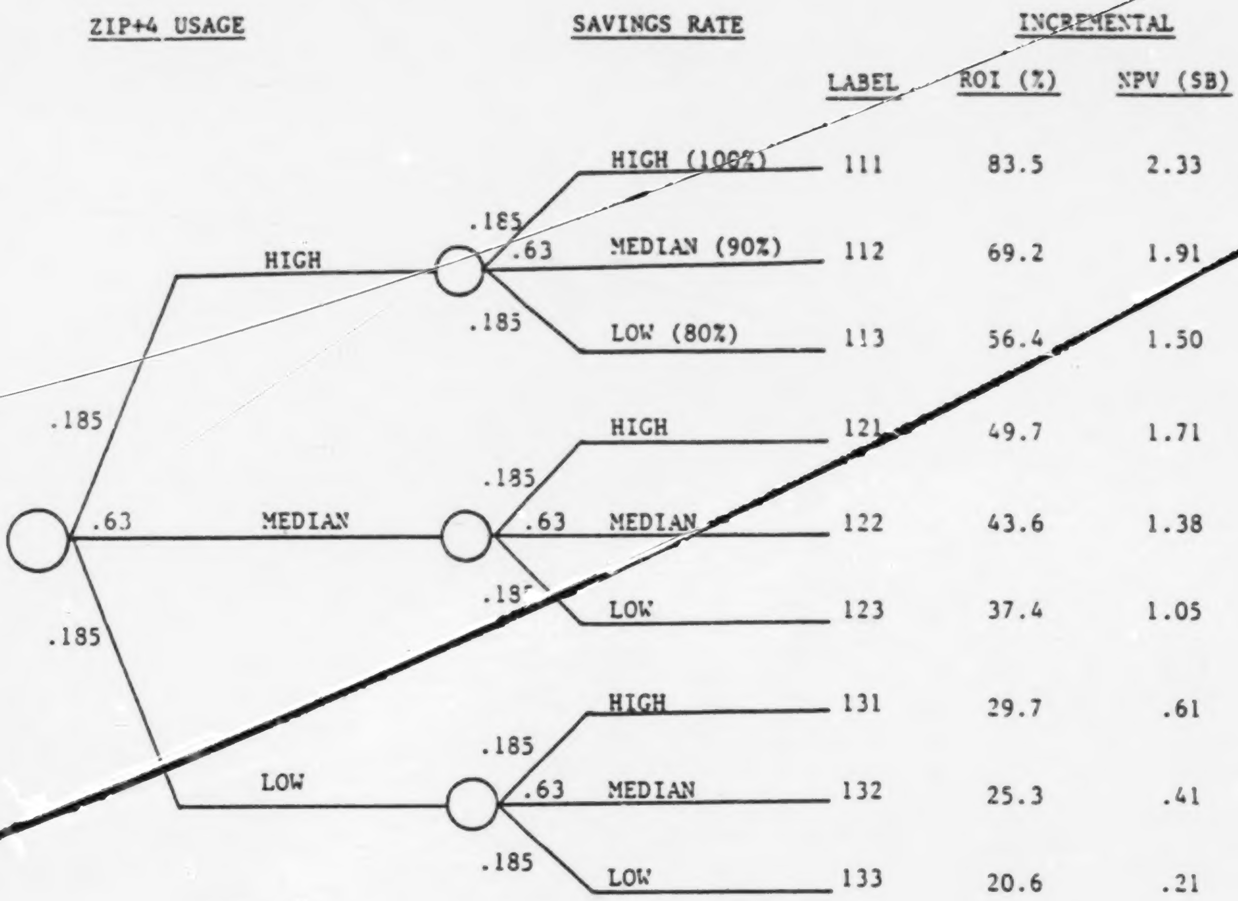
The detailed cash flow model and results for options A, B, C, D, and F are presented in this appendix. For each option, a complete probabilistic event tree is shown, along with the incremental rate of return (ROI) and net present value (NPV) over option F (cancel) for each condition of all options modeled. Also for each option, detailed year-by-year cash flows are shown for each condition.

The detailed cash flows show two ROIs and NPVs. The first ROI and NPV are for total cash flows of the option modeled. The second ROI and NPV are for total cash flows less cash flows for Option F (cancel).

All dollar figures are in thousands, and are carried to the nearest thousand dollars.

Figure B-1

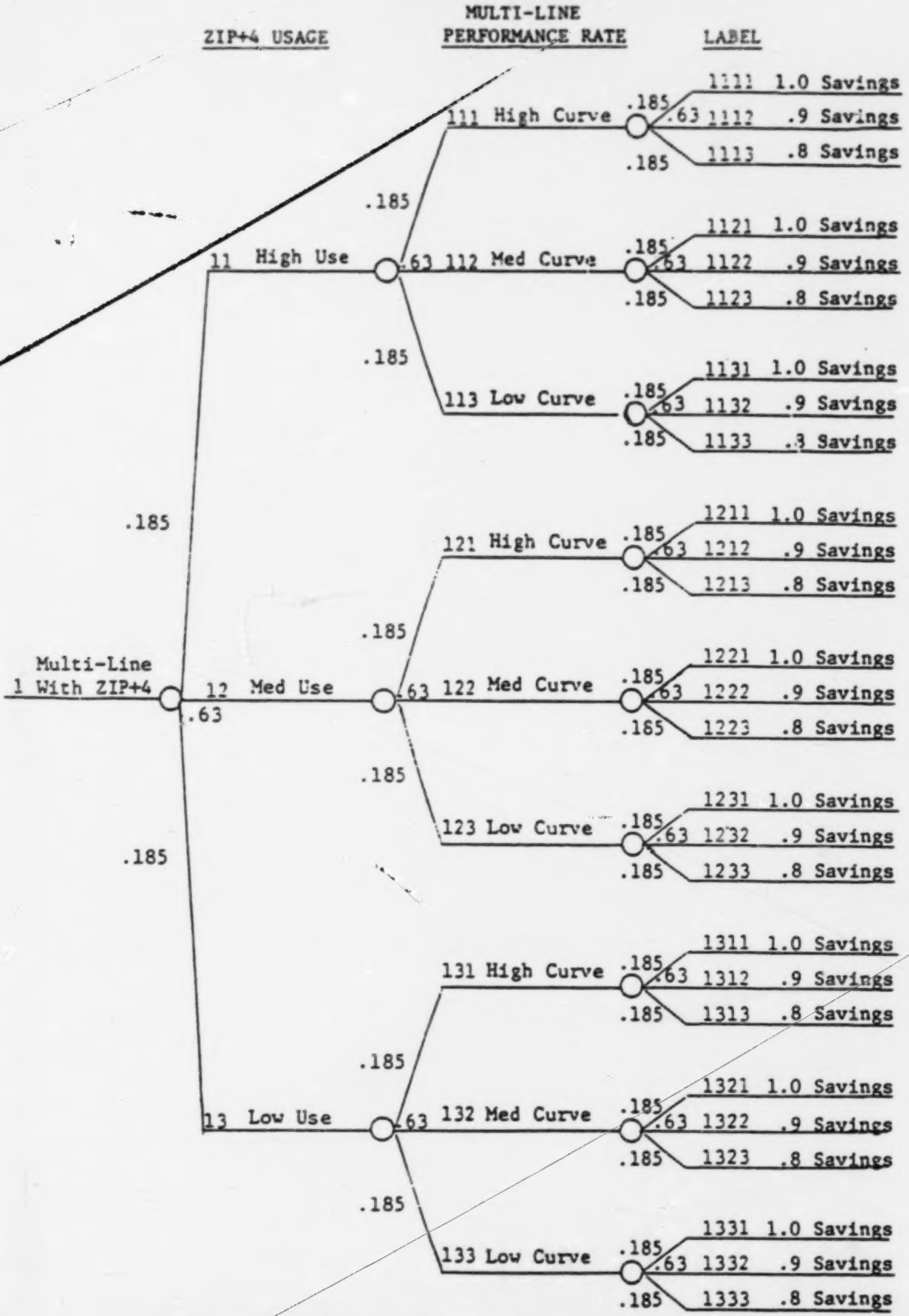
Cash Flow Model and Results for Option A: Single-Line OCR


ZIP+4 USAGE
SAVINGS RATE
INCREMENTAL
LABEL
ROI (%)
NPV ($B)
HIGH
MEDIAN
LOW
.185
.63
.185
HIGH (100%) 111 83.5 2.33
MEDIAN (90%) 112 69.2 1.91
LOW (80%) 113 56.4 1.50
HIGH 121 49.7 1.71
MEDIAN 122 43.6 1.38
LOW 123 37.4 1.05
HIGH 131 29.7 .61
MEDIAN 132 25.3 .41
LOW 133 20.6 .21

SOURCE: Office of Technology Assessment

Figure B-2

Cash Flow Model and Results for
Option B: Multi-Line OCR with ZIP+4

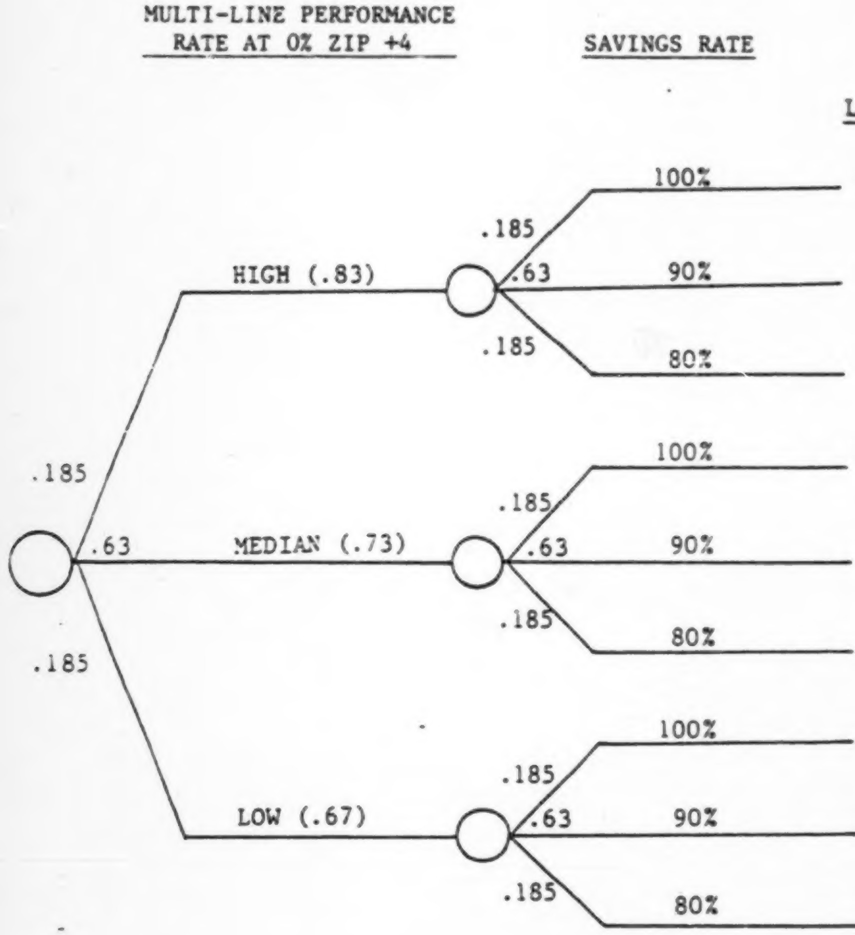

ZIP+4 USAGE
MULTI-LINE PERFORMANCE RATE
LABEL
Multi-Line
1 With ZIP+4
.185
.63
.185
11 High Use
12 Med Use
13 Low Use
.185
.63
.185
111 High Curve
112 Med Curve
113 Low Curve
121 High Curve
122 Med Curve
123 Low Curve
131 High Curve
132 Med Curve
133 Low Curve
.185
.63
.185

LABEL		Incremental ROI(%)	Incremental NPV($B)
1111	1.0 Savings	75.7	1.86
1112	.9 Savings	59.3	1.50
1113	.8 Savings	46.7	1.14
1121	1.0 Savings	75.5	1.84
1122	.9 Savings	59.0	1.48
1123	.8 Savings	46.4	1.12
1131	1.0 Savings	74.7	1.77
1132	.9 Savings	58.2	1.42
1133	.8 Savings	45.6	1.07
1211	1.0 Savings	47.5	1.55
1212	.9 Savings	41.5	1.24
1213	.8 Savings	35.4	.93
1221	1.0 Savings	47.0	1.51
1222	.9 Savings	41.0	1.21
1223	.8 Savings	35.0	.90
1231	1.0 Savings	45.7	1.41
1232	.9 Savings	39.7	1.12
1233	.8 Savings	33.7	.82
1311	1.0 Savings	37.8	1.20
1312	.9 Savings	33.8	.95
1313	.8 Savings	29.5	.70
1321	1.0 Savings	36.1	1.07
1322	.9 Savings	32.1	.83
1323	.8 Savings	27.8	.59
1331	1.0 Savings	30.8	.70
1332	.9 Savings	26.7	.50
1333	.8 Savings	22.3	.30

SOURCE: Office of Technology Assessment

Figure B-3

Cash Flow Results for
Option C: Multi-Line OCR Without ZIP+4

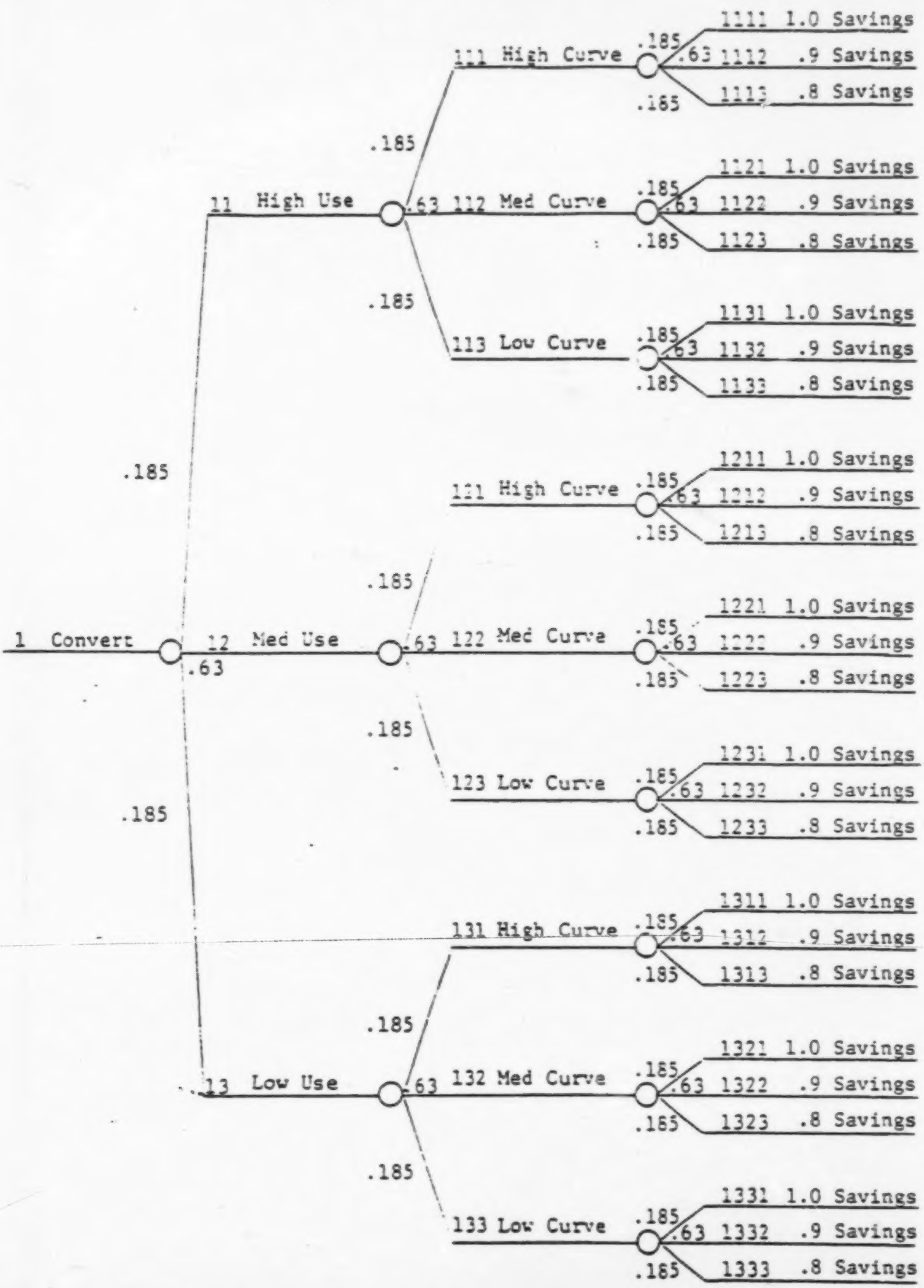

MULTI-LINE PERFORMANCE RATE AT 0% ZIP +4
SAVINGS RATE
.185
.63
.185
HIGH (.83)
MEDIAN (.73)
LOW (.67)
.185
.63
.185
100%
90%
80%
.185
.63
.185
100%
90%
80%
.185
.63
.185
100%
90%
80%

	INCREMENTAL	
LABEL	ROI (%)	NPV ($B)
111	48.5	1.36
112	43.1	1.11
113	37.6	.87
121	45.3	1.13
122	39.9	.91
123	34.4	.69
131	43.2	.99
132	37.8	.78
133	32.3	.58

SOURCE: Office of Technology Assessment

Figure 8-4

Cash Flow Results for
Option D: Automatic Conversion



ZIP+4 USAGE	MULTI-LINE PERFORMANCE RATE	LABEL	SAVINGS RATE	Incremental ROI(%)	Incremental NPV($B)
11 High Use	111 High Curve	1111	1.0 Savings	84.6	2.44
		1112	.9 Savings	70.2	2.01
		1113	.8 Savings	57.3	1.59
	112 Med Curve	1121	1.0 Savings	84.5	2.42
		1122	.9 Savings	70.0	1.99
		1123	.8 Savings	57.1	1.57
	113 Low Curve	1131	1.0 Savings	84.2	2.35
		1132	.9 Savings	69.6	1.93
		1133	.8 Savings	56.6	1.51
12 Med Use	121 High Curve	1211	1.0 Savings	51.5	1.90
		1212	.9 Savings	45.4	1.55
		1213	.8 Savings	39.2	1.19
	122 Med Curve	1221	1.0 Savings	51.2	1.87
		1222	.9 Savings	45.1	1.52
		1223	.8 Savings	38.8	1.17
	123 Low Curve	1231	1.0 Savings	50.3	1.77
		1232	.9 Savings	44.1	1.43
		1233	.8 Savings	37.8	1.09
13 Low Use	131 High Curve	1311	1.0 Savings	39.4	1.43
		1312	.9 Savings	35.4	1.15
		1313	.8 Savings	31.1	.86
	132 Med Curve	1321	1.0 Savings	38.1	1.30
		1322	.9 Savings	34.0	1.03
		1323	.8 Savings	29.7	.75
	133 Low Curve	1331	1.0 Savings	34.0	.93
		1332	.9 Savings	29.8	.70
		1333	.8 Savings	25.3	.46

SOURCE: Office of Technology Assessment

Table B-1

Detailed Cash Flows for Option A (Single-Line OCR) at High Savings Rate

111

ESCALATION FACTOR	1.0742													
BEGINNING OF YEAR USAGE	27%	48%	66%	85%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
AVERAGE USAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS INFORMATION	(32,400)	(30,900)	(15,700)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
EQUIPMENT INVESTMENT	(140,325)	(140,325)	(113,200)	0	0	0	0	0	0	0	0	0	0	0
PROGRAM CONTINGENCY	(14,033)	(14,033)	(11,320)	0	0	0	0	0	0	0	0	0	0	0
SITE PREPARATION	(6,044)	(6,044)	(4,827)	0	0	0	0	0	0	0	0	0	0	0
MAINTENANCE SUPPORT	(29,665)	(40,321)	(56,124)	(51,334)	(58,778)	(63,139)	(67,824)	(72,857)	(78,263)	(84,070)	(90,308)	(97,009)	(104,207)	(111,939)
EQUIPMENT SPARE PARTS	(991)	(5,475)	(15,244)	(14,842)	(15,943)	(17,126)	(18,397)	(19,762)	(21,228)	(22,803)	(24,495)	(26,313)	(28,265)	(30,362)
TOTAL INVESTMENT & MAINTENANCE	(223,458)	(237,098)	(216,415)	(82,876)	(92,721)	(99,601)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
CLERK SAVINGS	161,128	259,443	449,278	686,366	797,987	857,198	920,802	989,125	1,062,518	1,141,357	1,226,046	1,317,018	1,414,741	1,519,715
CARRIER SAVINGS	0	9,510	16,469	25,160	29,253	31,424	33,755	36,260	38,950	41,840	44,945	48,280	51,862	55,710
TOTAL SAVINGS	161,128	268,953	465,747	711,526	827,240	888,621	954,557	1,025,385	1,101,469	1,183,198	1,270,991	1,365,298	1,466,603	1,575,425
NET CASH FLOW	(120,663)	(56,812)	131,888	492,539	594,519	649,020	707,566	770,455	838,011	910,579	988,532	1,072,269	1,162,220	1,258,844
CASH FLOW - PHASE I	(175,132)	(91,696)	98,462	456,822	563,393	615,585	671,649	731,874	796,567	866,060	940,709	1,020,898	1,107,037	1,199,567

ROI 109.5% REDUCD ROI 83.5%
NPV 2,557,473 RED NPV 2,325,275

SOURCE: Office of Technology Assessment

Table B-1 (continued)

121

BEGINNING OF YEAR USAGE	12%	23%	33%	44%	51%	64%	76%	78%	82%	84%	87%	90%	90%	90%
AVERAGE USAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(223,458)	(237,098)	(216,415)	(82,876)	(92,721)	(99,601)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	75,193	132,117	237,500	306,257	591,994	733,112	845,976	935,664	1,034,004	1,136,609	1,254,309	1,365,298	1,466,603	1,575,425
NET CASH FLOW	(175,487)	(148,536)	(38,804)	229,492	409,828	524,623	619,207	696,289	781,435	870,991	974,184	1,072,269	1,162,220	1,258,844
CASH FLOW - PHASE I	(229,956)	(183,420)	(72,230)	193,775	378,702	491,187	583,291	657,708	739,990	826,471	926,361	1,020,898	1,107,037	1,199,567
ROI	60.1%		REDUCD ROI	49.7%										
NPV	1,945,794		RED NPV	1,713,596										

131

BEGINNING OF YEAR USAGE	6%	12%	18%	24%	30%	36%	40%	40%	40%	40%	40%	40%	40%	40%
AVERAGE USAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(223,458)	(237,098)	(216,415)	(82,876)	(92,721)	(99,601)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	38,671	70,777	129,546	219,557	414,654	484,299	536,938	576,779	619,576	665,549	714,932	767,980	824,964	886,177
NET CASH FLOW	(198,787)	(189,654)	(119,536)	94,681	270,600	325,587	367,725	399,627	433,896	470,708	510,251	552,729	598,358	647,373
CASH FLOW - PHASE I	(253,256)	(224,538)	(152,962)	58,964	239,474	292,151	331,808	361,045	392,452	426,189	462,429	501,358	543,175	588,096
ROI	37.4%		REDUCD ROI	29.7%										
NPV	844,867		RED NPV	612,668										

SOURCE: Office of Technology Assessment

Table B-2

Detailed Cash Flows for Option A (Single-Line OCR) at Median Savings Rate

112 REDUCED SAVINGS TO 90%

AVERAGE USEAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(223,458)	(237,098)	(216,415)	(82,876)	(92,721)	(99,601)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	145,015	242,058	419,172	640,373	744,516	799,759	859,101	922,847	991,322	1,064,878	1,143,892	1,228,769	1,319,943	1,417,883
NET CASH FLOW	(136,776)	(83,707)	85,313	421,386	511,795	560,158	612,110	667,916	727,864	792,259	861,433	935,739	1,015,559	1,101,302
CASH FLOW - PHASE I	(191,245)	(118,591)	51,887	385,669	480,669	526,723	576,193	629,335	686,420	747,740	813,610	884,368	960,376	1,042,024
ROI	89.0%		REDUCD ROI	69.2%										
NPV	2,143,372		RED NPV	1,911,173										

122

AVERAGE USEAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
TOTAL INVESTMENT & MAINTENANCE	(223,458)	(237,098)	(216,415)	(82,876)	(92,721)	(99,601)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	67,674	118,906	213,750	347,631	532,794	659,801	761,378	842,097	930,603	1,022,948	1,128,878	1,228,769	1,319,943	1,417,883
NET CASH FLOW	(183,006)	(161,748)	(62,554)	190,866	350,629	451,311	534,609	602,723	678,034	757,330	848,753	935,739	1,015,559	1,101,302
CASH FLOW - PHASE I	(237,475)	(196,632)	(95,980)	155,149	319,503	417,876	498,693	564,141	636,590	712,810	800,930	884,368	960,376	1,042,024
ROI	52.9%		REDUCD ROI	43.6%										
NPV	1,611,979		RED NPV	1,379,781										

132

AVERAGE USEAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
TOTAL INVESTMENT & MAINTENANCE	(223,458)	(237,098)	(216,415)	(82,876)	(92,721)	(99,601)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	34,804	63,699	116,591	197,601	373,189	435,869	483,244	519,101	557,618	598,994	643,439	691,182	742,468	797,559
NET CASH FLOW	(202,654)	(196,732)	(132,491)	72,725	229,134	277,157	314,031	341,949	371,938	404,153	438,758	475,931	515,862	558,756
CASH FLOW - PHASE I	(257,123)	(231,616)	(165,917)	37,008	198,008	243,721	278,114	303,367	330,494	359,634	390,935	424,560	460,679	499,478
ROI	32.7%		REDUCD ROI	25.3%										
NPV	644,771		RED NPV	412,572										

SOURCE: Office of Technology Assessment

Table B-3

Detailed Cash Flows for Option A (Single-Line OCR) at Low Savings Rate

113

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REDUCED SAVINGS         TO           80%

AVERAGE USEAGE                     37.5%     57.0%     75.5%     87.5%     90.0%     90.0%     90.0%     90.0%     90.0%     90.0%     90.0%     90.0%     90.0%     90.0%

YEAR                                   0         1         2         3         4         5         6         7         8         9        10        11        12        13
DATE                                1985      1986      1987      1988      1989      1990      1991      1992      1993      1994      1995      1996      1997      1998
                               --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
TOTAL INVESTMENT & MAINTENANCE (223,458) (237,098) (216,415)  (82,876)  (92,721)  (99,601) (106,991) (114,930) (123,458) (132,618) (142,459) (153,029) (164,384) (176,581)
RATE REDUCTION                  (58,333)  (88,667) (117,444) (136,111) (140,000) (140,000) (140,000) (140,000) (140,000) (140,000) (140,000) (140,000) (140,000) (140,000)
TOTAL SAVINGS                    128,902   215,162   372,598   569,221   661,792   710,897   763,646   820,308   881,175   946,558 1,016,793 1,092,239 1,173,283 1,260,340
                               --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
NET CASH FLOW                  (152,889) (110,602)    38,738   350,234   429,071   471,296   516,654   565,378   617,717   673,940   734,334   799,210   868,899   943,759
CASH FLOW - PHASE I            (207,358) (145,486)     5,312   314,517   397,945   437,861   480,738   526,797   576,273   629,420   686,511   747,838   813,716   884,482
                        ROI        71.7%                   REDUCD ROI      56.4%
                        NPV 1,729,271                      RED NPV    1,497,072
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123

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                               ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::

AVERAGE USEAGE                     17.5%     28.0%     38.5%     47.5%     57.5%     70.0%     77.0%     80.0%     83.0%     85.5%     88.5%     90.0%     90.0%     90.0%

TOTAL INVESTMENT & MAINTENANCE (223,458) (237,098) (216,415)  (82,876)  (92,721)  (99,601) (106,991) (114,930) (123,458) (132,618) (142,459) (153,029) (164,384) (176,581)
RATE REDUCTION                  (27,222)  (43,556)  (59,889)  (73,889)  (89,444) (108,889) (119,778) (124,444) (129,111) (133,000) (137,667) (140,000) (140,000) (140,000)
TOTAL SAVINGS                     60,154   105,694   190,000   309,006   473,595   586,490   676,781   748,531   827,203   909,287 1,003,447 1,092,239 1,173,283 1,260,340
                               --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
NET CASH FLOW                  (190,526) (174,960)  (86,304)   152,241   291,429   378,000   450,012   509,157   574,634   643,669   723,322   799,210   868,899   943,759
CASH FLOW - PHASE I            (244,995) (209,844) (119,730)   116,524   260,303   344,565   414,095   470,575   533,190   599,150   675,499   747,838   813,716   884,482
                        ROI        45.7%                   REDUCD ROI      37.4%
                        NPV 1,278,164                      RED NPV    1,045,966
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133

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                               ::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::::

AVERAGE USEAGE                      9.0%     15.0%     21.0%     27.0%     33.0%     38.0%     40.0%     40.0%     40.0%     40.0%     40.0%     40.0%     40.0%     40.0%

TOTAL INVESTMENT & MAINTENANCE (223,458) (237,098) (216,415)  (82,876)  (92,721)  (99,601) (106,991) (114,930) (123,458) (132,618) (142,459) (153,029) (164,384) (176,581)
RATE REDUCTION                  (14,000)  (23,333)  (32,667)  (42,000)  (51,333)  (59,111)  (62,222)  (62,222)  (62,222)  (62,222)  (62,222)  (62,222)  (62,222)  (62,222)
TOTAL SAVINGS                     30,937    56,622   103,636   175,645   331,723   387,439   429,551   461,423   495,661   532,439   571,946   614,384   659,972   708,941
                               --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- --------- ---------
NET CASH FLOW                  (206,521) (203,810) (145,445)    50,769   187,669   228,727   260,337   284,271   309,981   337,598   367,265   399,133   433,365   470,138
CASH FLOW - PHASE I            (260,990) (238,694) (178,871)    15,052   156,543   195,291   224,421   245,690   268,537   293,079   319,442   347,762   378,183   410,861
                        ROI        27.8%                   REDUCD ROI      20.6%
                        NPV   444,675                      RED NPV      212,476
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SOURCE: Office of Technology Assessment

Table B-4

Detailed Cash Flows for Option B (Multi-Line with ZIP+4) at High Performance Rate and High Savings Rate

1111

PRICE PER OCR	$850			HIGH CURVE										
NUMBER OF OCRs	655			==========										
ESCALATION FACTOR	1.0742													
BEGINNING OF YEAR USEAGE	27%	48%	66%	85%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
AVERAGE USEAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
BCS & EZR	(32,325)	(32,325)	(26,950)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(16,800)	(16,800)	(16,800)	0	0	0	0	0	0	0	0
NEW OCRs	0	0	0	(114,183)	(114,183)	(114,183)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
CLERK & CARRIER SAVINGS	161,128	214,754	276,599	343,181	435,811	630,435	1,015,649	1,091,010	1,171,963	1,258,922	1,352,334	1,452,677	1,560,466	1,676,253
NET CASH FLOW	(14,713)	3,613	58,718	16,437	89,143	241,426	768,657	836,080	908,505	986,304	1,069,876	1,159,648	1,256,082	1,359,671
CASH FLOW - PHASE I	(69,182)	(31,271)	25,292	(19,280)	58,017	207,991	732,741	797,498	867,061	941,784	1,022,053	1,108,277	1,200,899	1,300,394

ROI 181.6%   REDUCD ROI 75.7%

NPV 2,093,992   RED NPV 1,861,793

SOURCE: Office of Technology Assessment

Table B-4 (continued)

1211

BEGINNING OF YEAR USEAGE	12%	23%	33%	44%	51%	64%	76%	78%	82%	84%	87%	90%	90%	90%
AVERAGE USEAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	75,193	105,493	141,047	186,298	278,435	490,338	983,385	1,064,350	1,151,916	1,245,079	1,347,377	1,452,677	1,560,466	1,676,253
NET CASH FLOW	(69,537)	(60,536)	(19,279)	(78,224)	(17,678)	132,441	756,615	824,975	899,347	979,460	1,067,252	1,159,648	1,256,082	1,359,671
CASH FLOW - PHASE I	(124,006)	(95,420)	(52,705)	(113,941)	(48,804)	99,005	720,699	786,394	857,903	934,941	1,019,429	1,108,277	1,200,899	1,300,394

ROI 61.8%　　REDUCD ROI 47.5%
NPV 1,779,164　　RED NPV 1,546,966

1311

BEGINNING OF YEAR USEAGE	6%	12%	18%	24%	30%	36%	40%	40%	40%	40%	40%	40%	40%	40%
AVERAGE USEAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	38,671	56,514	76,935	105,896	159,797	266,184	891,556	957,710	1,028,772	1,105,107	1,187,105	1,275,189	1,369,808	1,471,447
NET CASH FLOW	(92,837)	(89,293)	(56,169)	(126,737)	(98,204)	(41,936)	722,343	780,557	843,092	910,266	982,424	1,059,937	1,143,201	1,232,644
CASH FLOW - PHASE I	(147,306)	(124,177)	(89,595)	(162,454)	(129,330)	(75,372)	686,426	741,976	801,647	865,746	934,602	1,008,566	1,088,019	1,173,366

ROI 47.0%　　REDUCD ROI 37.8%
NPV 1,436,073　　RED NPV 1,203,875

SOURCE: Office of Technology Assessment

Table B-5

Detailed Cash Flows for Option B (Multi-Line OCR with ZIP+4) at High Performance Rate and Median or Low Savings Rate

		PRICE PER OCR	$850		NUMBER	655										
	DATE		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1112	CF-PH I,SAVINGS @	90%,HI USE	(85,295)	(52,746)	(2,368)	(53,599)	14,436	144,947	631,176	688,397	749,864	815,892	886,819	963,009	1,044,853	1,132,769
		REDUCED ROI	59.3%		RED NPV	1,501,261										
1212	CF-PH I,SAVINGS @	90%,MED USE	(131,525)	(105,970)	(66,809)	(132,571)	(76,647)	49,971	622,361	679,959	742,711	810,433	884,692	963,009	1,044,853	1,132,769
		REDUCED ROI	41.5%		RED NPV	1,237,034										
1312	CF-PH I,SAVINGS @	90%,LOW USE	(151,173)	(129,829)	(97,288)	(173,044)	(145,310)	(101,990)	597,271	646,205	698,770	755,236	815,891	881,047	951,038	1,026,222
		REDUCED ROI	33.8%		RED NPV	951,878										
1113	CF-PH I,SAVINGS @	80%,HI USE	(101,408)	(74,221)	(30,028)	(87,917)	(29,146)	81,904	529,611	579,296	632,668	690,000	751,586	817,742	888,806	965,143
		REDUCED ROI	46.7%		RED NPV	1,140,728										
1213	CF-PH I,SAVINGS @	80%,MED USE	(139,045)	(116,519)	(80,914)	(151,201)	(104,491)	937	524,022	573,524	627,519	685,925	749,954	817,742	888,806	965,143
		REDUCED ROI	35.4%		RED NPV	927,103										
1313	CF-PH I,SAVINGS @	80%,LOW USE	(155,040)	(135,480)	(104,982)	(183,634)	(161,290)	(128,609)	508,115	550,434	595,893	644,725	697,181	753,528	814,057	879,077
		REDUCED ROI	29.5%		RED NPV	699,882										

SOURCE: Office of Technology Assessment

Table B-6

Detailed Cash Flows for Option B (Multi-Line with ZIP+4) at Median Performance Rate and High Savings Rate

1121

PRICE PER OCR	$850													
NUMBER OF OCRs	655			MED CURVE										
ESCALATION FACTOR	1.0742			*********										
BEGINNING OF YEAR USEAGE	27%	48%	66%	85%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
AVERAGE USEAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
BCS & E2R	(32,325)	(32,325)	(26,950)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(16,800)	(16,800)	(16,800)	0	0	0	0	0	0	0	0
NEW OCRs	0	0	0	(114,183)	(114,183)	(114,183)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
CLERK & CARRIER SAVINGS	161,128	214,754	276,599	343,181	435,811	630,435	1,006,103	1,080,756	1,160,948	1,247,090	1,339,624	1,439,024	1,545,800	1,660,498
NET CASH FLOW	(14,713)	3,613	58,718	16,437	89,143	241,426	759,112	825,826	897,490	974,472	1,057,166	1,145,995	1,241,416	1,343,917
CASH FLOW - PHASE I	(69,182)	(31,271)	25,292	(19,280)	58,017	207,991	723,195	787,244	856,046	929,952	1,009,343	1,094,624	1,186,233	1,284,640

ROI 181.4% REDUCD ROI 75.5%
NPV 2,071,102 RED NPV 1,838,903

SOURCE: Office of Technology Assessment

Table B-6 (continued)

1221

BEGINNING OF YEAR USEAGE	12%	23%	33%	44%	51%	64%	76%	78%	82%	84%	87%	90%	90%	90%
AVERAGE USEAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	75,193	105,493	141,047	186,298	278,435	490,338	961,430	1,043,842	1,133,191	1,227,922	1,332,761	1,439,024	1,545,800	1,660,498
NET CASH FLOW	(69,537)	(60,536)	(19,279)	(78,224)	(17,678)	132,441	734,661	804,467	880,622	962,304	1,052,636	1,145,995	1,241,416	1,343,917
CASH FLOW - PHASE I	(124,006)	(95,420)	(52,705)	(113,941)	(48,804)	99,005	698,744	765,886	839,178	917,785	1,004,813	1,094,624	1,186,233	1,284,640

ROI 61.3% REDUCD ROI 47.0%
NPV 1,744,339 RED NPV 1,512,141

1321

BEGINNING OF YEAR USEAGE	6%	12%	18%	24%	30%	36%	40%	40%	40%	40%	40%	40%	40%	40%
AVERAGE USEAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	38,671	56,514	76,935	105,896	159,797	266,184	834,283	896,187	962,684	1,034,115	1,110,846	1,193,271	1,281,811	1,376,922
NET CASH FLOW	(92,837)	(89,293)	(56,169)	(126,737)	(98,204)	(41,936)	665,069	719,034	777,003	839,274	906,165	978,019	1,055,205	1,138,118
CASH FLOW - PHASE I	(147,306)	(124,177)	(89,595)	(162,454)	(129,330)	(75,372)	629,153	680,453	735,559	794,755	858,342	926,648	1,000,022	1,078,841

ROI 45.2% REDUCD ROI 36.1%
NPV 1,298,732 RED NPV 1,066,533

SOURCE: Office of Technology Assessment

Table B-7

Detailed Cash Flows for Option B (Multi-Line with ZIP+4) at Median Performance and Median or Low Savings Rate

	PRICE PER OCR	$850		NUMBER	655										
	DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1122	CF-PH I,SAVINGS @ 90%,HI USE	(85,295)	(52,746)	(2,368)	(53,599)	14,436	144,947	622,585	679,169	739,951	805,243	875,380	950,722	1,031,653	1,118,590
	REDUCED ROI	59.0%		RED NPV	1,480,659										
1222	CF-PH I,SAVINGS @ 90%,MED USE	(131,525)	(105,970)	(66,809)	(132,571)	(76,647)	49,971	602,601	661,502	725,859	794,992	871,537	950,722	1,031,653	1,118,590
	REDUCED ROI	41.0%		RED NPV	1,205,692										
1322	CF-PH I,SAVINGS @ 90%,LOW USE	(151,173)	(129,829)	(97,288)	(173,044)	(145,310)	(101,990)	545,724	590,834	639,291	691,343	747,258	807,321	871,841	941,149
	REDUCED ROI	32.1%		RED NPV	828,271										
1123	CF-PH I,SAVINGS @ 80%,HI USE	(101,408)	(74,221)	(30,028)	(87,917)	(29,146)	81,904	521,975	571,093	623,856	680,534	741,418	806,819	877,073	952,540
	REDUCED ROI	46.4%		RED NPV	1,122,416										
1223	CF-PH I,SAVINGS @ 80%,MED USE	(139,045)	(116,519)	(80,914)	(151,201)	(104,491)	937	506,458	557,118	612,540	672,200	738,261	806,819	877,073	952,540
	REDUCED ROI	35.0%		RED NPV	899,243										
1323	CF-PH I,SAVINGS @ 80%,LOW USE	(155,040)	(135,480)	(104,982)	(183,634)	(161,290)	(128,609)	462,296	501,215	543,023	587,932	636,173	687,994	743,660	803,457
	REDUCED ROI	27.8%		RED NPV	590,009										

SOURCE: Office of Technology Assessment

Table B-8

Detailed Cash Flows for Option B (Multi-Line with ZIP+4) at Low Performance Rate and High Savings Rate

1131

PRICE PER OCR $850
NUMBER OF OCRs 655
ESCALATION FACTOR 1.0742

LOW CURVE

BEGINNING OF YEAR USEAGE	27%	48%	66%	85%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
AVERAGE USEAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
BCS & EZR	(32,325)	(32,325)	(26,950)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(16,800)	(16,800)	(16,800)	0	0	0	0	0	0	0	0
NEW OCRs	0	0	0	(114,183)	(114,183)	(114,183)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
CLERK & CARRIER SAVINGS	161,128	214,754	276,599	343,181	435,811	630,435	978,230	1,050,815	1,128,785	1,212,541	1,302,511	1,399,158	1,502,975	1,614,496
NET CASH FLOW	(14,713)	3,613	58,718	16,437	89,143	241,426	731,239	795,885	865,327	939,922	1,020,053	1,106,129	1,198,591	1,297,915
CASH FLOW - PHASE I	(69,182)	(31,271)	25,292	(19,280)	58,017	207,991	695,322	757,303	823,883	895,403	972,230	1,054,757	1,143,408	1,238,637

ROI 180.9%
NPV 2,004,262

REDUCD ROI 74.7%
RED NPV 1,772,064

SOURCE: Office of Technology Assessment

Table B-8 (continued)

1231

BEGINNING OF YEAR USEAGE	12%	23%	33%	44%	51%	64%	76%	78%	82%	84%	87%	90%	90%	90%
AVERAGE USEAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	75,193	105,493	141,047	186,298	278,435	490,338	901,044	987,036	1,080,827	1,179,423	1,290,653	1,399,158	1,502,975	1,614,496
NET CASH FLOW	(69,537)	(60,536)	(19,279)	(78,224)	(17,678)	132,441	674,275	747,661	828,258	913,805	1,010,528	1,106,129	1,198,591	1,297,915
CASH FLOW - PHASE I	(124,006)	(95,420)	(52,705)	(113,941)	(48,804)	99,005	638,359	709,080	786,814	869,285	962,705	1,054,757	1,143,408	1,238,637

ROI 59.9% REDUCD ROI 45.7%
NPV 1,646,231 RED NPV 1,414,032

1331

BEGINNING OF YEAR USEAGE	6%	12%	18%	24%	30%	36%	40%	40%	40%	40%	40%	40%	40%	40%
AVERAGE USEAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	38,671	56,514	76,935	105,896	159,797	266,184	681,363	731,920	786,228	844,566	907,233	974,550	1,046,862	1,124,539
NET CASH FLOW	(92,837)	(89,293)	(56,169)	(126,737)	(98,204)	(41,936)	512,149	554,768	600,548	649,726	702,552	759,299	820,255	885,735
CASH FLOW - PHASE I	(147,306)	(124,177)	(89,595)	(162,454)	(129,330)	(75,372)	476,233	516,186	559,104	605,206	654,730	707,927	765,073	826,458

ROI 39.7% REDUCD ROI 30.8%
NPV 932,031 RED NPV 699,832

SOURCE: Office of Technology Assessment

Table B-9

Detailed Cash Flows for Alternative B (Multi-Line with ZIP+4) at Low Performance Rate and Median or Low Savings Rate

		1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
	PRICE PER OCR	$850		NUMBER	655										
	DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1132	CF-PH I,SAVINGS @ 90%,HI USE	(85,295)	(52,746)	(2,368)	(53,599)	14,436	144,947	597,499	652,222	711,004	774,149	841,979	914,842	993,111	1,077,188
	REDUCED ROI	58.2%		RED NPV	1,420,504										
1232	CF-PH I,SAVINGS @ 90%,MED USE	(131,525)	(105,970)	(66,809)	(132,571)	(76,647)	49,971	548,254	610,376	678,731	751,343	833,640	914,842	993,111	1,077,188
	REDUCED ROI	39.7%		RED NPV	1,117,394										
1332	CF-PH I,SAVINGS @ 90%,LOW USE	(151,173)	(129,829)	(97,288)	(173,044)	(145,310)	(101,990)	408,096	442,994	480,481	520,750	564,006	610,472	660,386	714,004
	REDUCED ROI	26.7%		RED NPV	498,240										
1133	CF-PH I,SAVINGS @ 80%,HI USE	(101,408)	(74,221)	(30,028)	(87,917)	(29,146)	81,904	499,676	547,140	598,126	652,895	711,728	774,926	842,813	915,738
	REDUCED ROI	45.6%		RED NPV	1,068,944										
1233	CF-PH I,SAVINGS @ 80%,MED USE	(139,045)	(116,519)	(80,914)	(151,201)	(104,491)	937	458,150	511,673	570,648	633,401	704,574	774,926	842,813	915,738
	REDUCED ROI	33.7%		RED NPV	820,756										
1633	CF-PH I,SAVINGS @ 80%,LOW USE	(155,040)	(135,480)	(104,982)	(183,634)	(161,290)	(128,609)	339,960	369,802	401,858	436,293	473,283	513,017	555,700	601,550
	REDUCED ROI	22.3%		RED NPV	296,648										

SOURCE: Office of Technology Assessment

Table B-10

Detailed Cash Flows for Option C (Multi-Line OCR Without ZIP+4) at High Performance Rate

111

PRICE PER OCR $850
NUMBER OF OCRs 655
ESCALATION FACTOR 1.0742
CURVE FACTOR 0.83

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
BCS & EZR	(32,325)	(32,325)	(26,950)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(16,800)	(16,800)	(16,800)	0	0	0	0	0	0	0	0
NEW OCRs	0	0	0	(114,183)	(114,183)	(114,183)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CLERK & CARRIER SAVINGS	82,175	72,056	70,066	75,010	190,058	498,441	792,282	851,070	914,219	982,054	1,054,922	1,133,198	1,217,281	1,307,603
NET CASH FLOW	(35,333)	(50,418)	(30,371)	(115,623)	(16,610)	249,432	685,291	736,140	790,761	849,436	912,464	980,168	1,052,897	1,131,022
CASH FLOW - PHASE I	(89,802)	(85,302)	(63,797)	(151,340)	(47,736)	215,997	649,374	697,558	749,317	804,916	864,641	928,797	997,714	1,071,744

ROI 67.5% REDUCD ROI 48.5%
NPV 1,587,975 RED NPV 1,355,776

PRICE PER OCR $850 NUMBER 655

DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
CF-PH I,SAVINGS @ 90%	(98,020)	(92,508)	(70,804)	(158,841)	(66,742)	166,152	570,146	612,451	657,895	706,711	759,149	815,478	875,986	940,984
CF-PH I,SAVINGS @ 80%	(106,237)	(99,713)	(77,810)	(166,342)	(85,748)	116,308	490,918	527,344	566,473	608,505	653,656	702,158	754,258	810,224

112 REDUCED ROI 43.1% RED NPV 1,113,300

113 REDUCED ROI 37.6% RED NPV 870,823

SOURCE: Office of Technology Assessment

Table B-11

Detailed Cash Flows for Option C (Multi-Line OCR Without ZIP+4) at Median Performance Rate

121

PRICE PER OCR $850 CURVE FACTOR 0.73
NUMBER OF OCRs 655
ESCALATION FACTOR 1.0742

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
BCS & EZR	(32,325)	(32,325)	(26,950)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(16,800)	(16,800)	(16,800)	0	0	0	0	0	0	0	0
NEW OCRs	0	0	0	(114,183)	(114,183)	(114,183)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CLERK & CARRIER SAVINGS	82,175	72,056	70,066	75,010	190,058	498,441	696,827	748,531	804,072	863,734	927,823	996,668	1,070,621	1,150,061
NET CASH FLOW	(35,333)	(50,418)	(30,371)	(115,623)	(16,610)	249,432	589,835	633,601	680,614	731,116	785,365	843,639	906,237	973,479
CASH FLOW - PHASE I	(89,802)	(85,302)	(63,797)	(151,340)	(47,736)	215,997	553,919	595,020	639,170	686,596	737,542	792,267	851,054	914,202

ROI 64.0% REDUCD ROI 45.3%
NPV 1,359,073 RED NPV 1,126,874

PRICE PER OCR $850 NUMBER 655

DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
CF-PH I,SAVINGS @ 90%	(98,020)	(92,508)	(70,804)	(158,841)	(66,742)	166,152	484,236	520,166	558,763	600,223	644,760	692,601	743,992	799,196
REDUCED ROI	39.9%		RED NPV	907,288										
CF-PH I,SAVINGS @ 80%	(106,237)	(99,713)	(77,810)	(166,342)	(85,748)	116,308	414,553	445,313	478,356	513,850	551,977	592,934	636,930	684,190
REDUCED ROI	34.4%		RED NPV	687,701										

122

123

SOURCE: Office of Technology Assessment

Table B-12

Detailed Cash Flows for Option C (Multi-Line OCR Without ZIP+4) at Low Performance Rate

131

PRICE PER OCR $850 CURVE FACTOR
NUMBER OF OCRs 655 0.67
ESCALATION FACTOR 1.0742

YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
BCS & EZR	(32,325)	(32,325)	(26,950)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(16,800)	(16,800)	(16,800)	0	0	0	0	0	0	0	0
NEW OCRs	0	0	0	(114,183)	(114,183)	(114,183)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(117,508)	(122,474)	(100,437)	(190,633)	(206,668)	(249,009)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	0	0	0	0	0	0	0	0	0	0	0	0	0	0
CLERK & CARRIER SAVINGS	82,175	72,056	70,066	75,010	190,058	498,441	639,553	687,008	737,984	792,742	851,564	914,750	982,624	1,055,535
NET CASH FLOW	(35,333)	(50,418)	(30,371)	(115,623)	(16,610)	249,432	532,562	572,078	614,526	660,124	709,105	761,721	818,240	878,954
CASH FLOW - PHASE I	(89,802)	(85,302)	(63,797)	(151,340)	(47,736)	215,997	496,645	533,496	573,082	615,605	661,282	710,350	763,058	819,676

ROI 61.7% REDUCD ROI 43.2%
NPV 1,221,732 RED NPV 989,533

PRICE PER OCR $850 NUMBER 655

DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
CF-PH I,SAVINGS @ 90%	(98,020)	(92,508)	(70,804)	(158,841)	(66,742)	166,152	432,690	464,796	499,283	536,330	576,126	618,875	664,795	714,123
132 REDUCED ROI	37.8%		RED NPV	783,681										
CF-PH I,SAVINGS @ 80%	(106,237)	(99,713)	(77,810)	(166,342)	(85,748)	116,308	368,735	396,095	425,485	457,056	490,970	527,400	566,533	608,569
133 REDUCED ROI	32.3%		RED NPV	577,829										

SOURCE: Office of Technology Assessement

Table B-13

Detailed Cash Flows for Option D (Automatic Conversion) at High Performance Rate and High Savings Rate

1111

CONVERT
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ESCALATION FACTOR	1.0742													
BEGINNING OF YEAR USEAGE	27%	48%	66%	85%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
AVERAGE USEAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
SINGLE-LINE EQUIPMENT	(140,325)	(140,325)	(113,200)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(43,667)	(43,667)	(43,667)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
CLERK & CARRIER SAVINGS	161,128	268,953	465,747	711,526	827,240	888,621	1,015,649	1,091,010	1,171,963	1,258,922	1,352,334	1,452,677	1,560,466	1,676,253
NET CASH FLOW	(122,713)	(50,188)	161,616	472,098	567,888	586,929	768,657	836,080	908,505	986,304	1,069,876	1,159,648	1,256,082	1,359,671
CASH FLOW - PHASE I	(177,182)	(85,072)	128,190	436,381	536,762	553,493	732,741	797,498	867,061	941,784	1,022,053	1,108,277	1,200,899	1,300,394

ROI 111.3% REDUCD ROI 84.6%
NPV 2,674,972 RED NPV 2,442,773

SOURCE: Office of Technology Assessment

Table B-13 (continued)

1211

BEGINNING OF YEAR USEAGE	12%	23%	33%	44%	51%	64%	76%	78%	82%	84%	87%	90%	90%	90%
AVERAGE USEAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	75,193	132,117	237,500	386,257	591,994	733,112	983,385	1,064,350	1,151,916	1,245,079	1,347,377	1,452,677	1,560,466	1,676,253
NET CASH FLOW	(177,537)	(141,912)	(9,076)	209,051	383,197	462,531	756,615	824,975	899,347	979,460	1,067,252	1,159,648	1,256,082	1,359,671
CASH FLOW - PHASE I	(232,006)	(176,796)	(42,502)	173,334	352,071	429,095	720,699	786,394	857,903	934,941	1,019,429	1,108,277	1,200,899	1,300,394

ROI 62.0% REDUCD ROI 51.5%
NPV 2,136,691 RED NPV 1,904,493

1311

BEGINNING OF YEAR USEAGE	6%	12%	18%	24%	30%	36%	40%	40%	40%	40%	40%	40%	40%	40%
AVERAGE USEAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	38,671	70,777	129,546	219,557	414,654	484,299	891,556	957,710	1,028,772	1,105,107	1,187,105	1,275,189	1,369,808	1,471,447
NET CASH FLOW	(200,837)	(183,030)	(89,808)	74,240	243,969	263,495	722,343	780,557	843,092	910,266	982,424	1,059,937	1,143,201	1,232,644
CASH FLOW - PHASE I	(255,306)	(217,914)	(123,234)	38,523	212,843	230,059	686,426	741,976	801,647	865,746	934,602	1,008,566	1,088,019	1,173,366

ROI 46.6% REDUCD ROI 39.4%
NPV 1,666,239 RED NPV 1,434,041

SOURCE: Office of Technology Assessment

Table B-14

Detailed Cash Flows for Option D (Automatic Conversion) at High Performance Rate and Median or Low Savings Rate

	DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1112	CF-PH I,SAVINGS @ 90%,HI USE	(193,295)	(111,967)	81,615	365,228	454,038	464,631	631,176	688,397	749,864	815,892	886,819	963,009	1,044,853	1,132,769
	REDUCED ROI	70.2%		RED NPV	2,014,022										
1212	CF-PH I,SAVINGS @ 90%,MED USE	(239,525)	(190,008)	(66,252)	134,708	292,872	355,784	622,361	679,959	742,711	810,433	884,692	963,009	1,044,853	1,132,769
	REDUCED ROI	45.4%		RED NPV	1,548,688										
1312	CF-PH I,SAVINGS @ 90%,LOW USE	(259,173)	(224,992)	(136,189)	16,567	171,377	181,629	597,271	646,205	698,770	755,236	815,891	881,047	951,038	1,026,222
	REDUCED ROI	35.4%		RED NPV	1,148,907										
1113	CF-PH I,SAVINGS @ 80%,HI USE	(209,408)	(138,862)	35,040	294,076	371,314	375,769	529,611	579,296	632,668	690,000	751,586	817,742	888,806	965,143
	REDUCED ROI	57.3%		RED NPV	1,585,271										
1213	CF-PH I,SAVINGS @ 80%,MED USE	(247,045)	(203,220)	(90,002)	96,083	233,672	282,473	524,022	573,524	627,519	685,925	749,954	817,742	888,806	965,143
	REDUCED ROI	39.2%		RED NPV	1,192,884										
1313	CF-PH I,SAVINGS @ 80%,LOW USE	(263,040)	(232,070)	(149,143)	(5,389)	129,912	133,200	508,115	550,434	595,893	644,725	697,181	753,528	814,057	879,077
	REDUCED ROI	31.1%		RED NPV	863,774										

SOURCE: Office of Technology Assessment

Table B-15

Detailed Cash Flows for Option D (Automatic Conversion) at Median Performance and High Savings Rate

1121

CONVERT
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ESCALATION FACTOR	1.0742													
BEGINNING OF YEAR USEAGE	27%	48%	66%	85%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
AVERAGE USEAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
SINGLE-LINE EQUIPMENT	(140,325)	(140,325)	(113,200)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(43,667)	(43,667)	(43,667)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140.000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
CLERK & CARRIER SAVINGS	161,128	268,953	465,747	711,526	827,240	888,621	1,006,103	1,080,756	1,160,948	1,247,090	1,339,624	1,439,024	1,545,800	1,660,498
NET CASH FLOW	(122,713)	(50,188)	161,616	472,098	567,888	586,929	759,112	825,826	897,490	974,472	1,057,166	1,145,995	1,241,416	1,343,917
CASH FLOW - PHASE I	(177,182)	(85,072)	128,190	436,381	536,762	553,493	723,195	787,244	856,046	929,952	1,009,343	1,094,624	1,186,233	1,284,640

ROI 111.2% REDUCD ROI 84.5%
NPV 2,652,082 RED NPV 2,419,883

SOURCE: Office of Technology Assessment

Table B-15 (continued)

1221

BEGINNING OF YEAR USEAGE	12%	23%	33%	44%	51%	64%	76%	78%	82%	84%	87%	90%	90%	90%
AVERAGE USEAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	75,193	132,117	237,500	386,257	591,994	733,112	961,430	1,043,842	1,133,191	1,227,922	1,332,761	1,439,024	1,545,800	1,660,498
NET CASH FLOW	(177,537)	(141,912)	(9,076)	209,051	383,197	462,531	734,661	804,467	880,622	962,304	1,052,636	1,145,995	1,241,416	1,343,917
CASH FLOW - PHASE I	(232,006)	(176,796)	(42,502)	173,334	352,071	429,095	698,744	765,886	839,178	917,705	1,004,813	1,094,624	1,186,233	1,284,640

ROI 61.7% REDUCD ROI 51.2%
NPV 2,101,867 RED NPV 1,869,668

1321

BEGINNING OF YEAR USEAGE	6%	12%	18%	24%	30%	36%	40%	40%	40%	40%	40%	40%	40%	40%
AVERAGE USEAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	38,671	70,777	129,546	219,557	414,654	484,299	834,283	896,187	962,684	1,034,115	1,110,846	1,193,271	1,281,811	1,376,922
NET CASH FLOW	(200,837)	(183,030)	(89,808)	74,240	243,969	263,495	665,069	719,034	777,003	839,274	906,165	978,019	1,055,205	1,138,118
CASH FLOW - PHASE I	(255,306)	(217,914)	(123,234)	38,523	212,843	230,059	629,153	680,453	735,559	794,755	858,342	926,648	1,000,022	1,078,841

ROI 45.3% REDUCD ROI 38.1%
NPV 1,528,898 RED NPV 1,296,699

SOURCE: Office of Technology Assessment

Table B-16

Detailed Cash Flows for Option D (Automatic Conversion) at Median Performance and Median or Low Savings Rate

	DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1122	CF-PH I,SAVINGS @ 90%,HI USE	(193,295)	(111,967)	81,615	365,228	454,038	464,631	622,585	679,169	739,951	805,243	875,380	950,722	1,031,653	1,118,590
	REDUCED ROI	70.0%		RED NPV	1,993,421										
1222	CF-PH I,SAVINGS @ 90%,MED USE	(239,525)	(190,008)	(66,252)	134,708	292,872	355,784	602,601	661,502	725,859	794,992	871,537	950,722	1,031,653	1,118,590
	REDUCED ROI	45.1%		RED NPV	1,517,346										
1322	CF-PH I,SAVINGS @ 90%,LOW USE	(259,173)	(224,992)	(136,189)	16,567	171,377	181,629	545,724	590,834	639,291	691,343	747,258	807,321	871,841	941,149
	REDUCED ROI	34.0%		RED NPV	1,025,300										
1123	CF-PH I,SAVINGS @ 80%,HI USE	(209,408)	(138,862)	35,040	294,076	371,314	375,769	521,975	571,093	623,856	680,534	741,418	806,819	877,073	952,540
	REDUCED ROI	57.1%		RED NPV	1,566,959										
1223	CF-PH I,SAVINGS @ 80%,MED USE	(247,045)	(203,220)	(90,002)	96,083	233,672	282,473	506,458	557,118	612,540	672,200	738,261	806,819	877,073	952,540
	REDUCED ROI	38.8%		RED NPV	1,165,024										
1323	CF-PH I,SAVINGS @ 80%,LOW USE	(263,040)	(232,070)	(149,143)	(5,389)	129,912	133,200	462,296	501,215	543,023	587,932	636,173	687,994	743,660	803,457
	REDUCED ROI	29.7%		RED NPV	753,901										

SOURCE: Office of Technology Assessment

Table B-17

Detailed Cash Flows for Option D (Automatic Conversion) at Low Performance and High Savings Rate

1131

CONVERT														
ESCALATION FACTOR	1.0742													
BEGINNING OF YEAR USEAGE	27%	48%	66%	85%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%
AVERAGE USEAGE	37.5%	57.0%	75.5%	87.5%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%	90.0%
YEAR	0	1	2	3	4	5	6	7	8	9	10	11	12	13
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
ADDRESS, SITE, & CONTINGENCY	(52,477)	(50,977)	(31,847)	(16,700)	(18,000)	(19,336)	(20,770)	(22,311)	(23,967)	(25,745)	(27,656)	(29,708)	(31,912)	(34,280)
RESEARCH	(5,000)	(5,000)	(5,000)	0	0	0	0	0	0	0	0	0	0	0
SINGLE-LINE EQUIPMENT	(140,325)	(140,325)	(113,200)	0	0	0	0	0	0	0	0	0	0	0
OCR UPGRADE	0	0	0	(43,667)	(43,667)	(43,667)	0	0	0	0	0	0	0	0
MAINTENANCE & SPARES	(27,706)	(34,172)	(36,640)	(42,950)	(57,685)	(98,690)	(86,221)	(92,619)	(99,491)	(106,873)	(114,803)	(123,321)	(132,472)	(142,301)
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(58,333)	(88,667)	(117,444)	(136,111)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)	(140,000)
CLERK & CARRIER SAVINGS	161,128	268,953	465,747	711,526	827,240	888,621	978,230	1,050,815	1,128,785	1,212,541	1,302,511	1,399,158	1,502,975	1,614,496
NET CASH FLOW	(122,713)	(50,188)	161,616	472,098	567,888	586,929	731,239	795,885	865,327	939,922	1,020,053	1,106,129	1,198,591	1,297,915
CASH FLOW - PHASE I	(177,182)	(85,072)	128,190	436,381	536,762	553,493	695,322	757,303	823,883	895,403	972,230	1,054,757	1,143,408	1,238,637

ROI 110.9% REDUCD ROI 84.2%
NPV 2,585,242 RED NPV 2,353,043

SOURCE: Office of Technology Assessment

Table B-17 (continued)

1231

BEGINNING OF YEAR USEAGE	12%	23%	33%	44%	51%	64%	76%	78%	82%	84%	87%	90%	90%	90%
AVERAGE USEAGE	17.5%	28.0%	38.5%	47.5%	57.5%	70.0%	77.0%	80.0%	83.0%	85.5%	88.5%	90.0%	90.0%	90.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(27,222)	(43,556)	(59,889)	(73,889)	(89,444)	(108,889)	(119,778)	(124,444)	(129,111)	(133,000)	(137,667)	(140,000)	(140,000)	(140,000)
TOTAL SAVINGS	75,193	132,117	237,500	386,257	591,994	733,112	901,044	987,036	1,080,827	1,179,423	1,290,653	1,399,158	1,502,975	1,614,496
NET CASH FLOW	(177,537)	(141,912)	(9,076)	209,051	383,197	462,531	674,275	747,661	828,258	913,805	1,010,528	1,106,129	1,198,591	1,297,915
CASH FLOW - PHASE I	(232,006)	(176,796)	(42,502)	173,334	352,071	429,095	638,359	709,080	786,814	869,285	962,705	1,054,757	1,143,408	1,238,637

ROI 60.8% REDUCD ROI 50.3%
NPV 2,003,758 RED NPV 1,771,559

1331

BEGINNING OF YEAR USEAGE	6%	12%	18%	24%	30%	36%	40%	40%	40%	40%	40%	40%	40%	40%
AVERAGE USEAGE	9.0%	15.0%	21.0%	27.0%	33.0%	38.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%	40.0%
DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
TOTAL INVESTMENT & MAINTENANCE	(225,508)	(230,474)	(186,687)	(103,317)	(119,352)	(161,693)	(106,991)	(114,930)	(123,458)	(132,618)	(142,459)	(153,029)	(164,384)	(176,581)
RATE REDUCTION	(14,000)	(23,333)	(32,667)	(42,000)	(51,333)	(59,111)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)	(62,222)
TOTAL SAVINGS	38,671	70,777	129,546	219,557	414,654	484,299	681,363	731,920	786,228	844,566	907,233	974,550	1,046,862	1,124,539
NET CASH FLOW	(200,837)	(183,030)	(89,808)	74,240	243,969	263,495	512,149	554,768	600,548	649,726	702,552	759,299	820,255	885,735
CASH FLOW - PHASE I	(255,306)	(217,914)	(123,234)	38,523	212,843	230,059	476,233	516,186	559,104	605,206	654,730	707,927	765,073	826,458

ROI 41.4% REDUCD ROI 34.0%
NPV 1,162,197 RED NPV 929,998

SOURCE: Office of Technology Assessment

Table B-18

Detailed Cash Flows for Alternative D (Automatic Conversion) at Low Performance Rate and Median or Low Savings Rate

	DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
1132	CF-PH I,SAVINGS @ 90%,HI USE	(193,295)	(111,967)	81,615	365,228	454,038	464,631	597,499	652,222	711,004	774,149	841,979	914,842	993,111	1,077,188
	REDUCED ROI	69.6%		RED NPV	1,933,266										
1232	CF-PH I,SAVINGS @ 90%,MED USE	(239,525)	(190,008)	(66,252)	134,708	292,872	355,784	548,254	610,376	678,731	751,343	833,640	914,842	993,111	1,077,188
	REDUCED ROI	44.1%		RED NPV	1,429,048										
1332	CF-PH I,SAVINGS @ 90%,LOW USE	(259,173)	(224,992)	(136,189)	16,567	171,377	181,629	408,096	442,994	480,481	520,750	564,006	610,472	660,386	714,004
	REDUCED ROI	29.8%		RED NPV	695,269										
1133	CF-PH I,SAVINGS @ 80%,HI USE	(209,408)	(138,862)	35,040	294,076	371,314	375,769	499,676	547,140	598,126	652,895	711,728	774,926	842,813	915,738
	REDUCED ROI	56.6%		RED NPV	1,513,488										
1233	CF-PH I,SAVINGS @ 80%,MED USE	(247,045)	(203,220)	(90,002)	96,083	233,672	282,473	458,150	511,673	570,648	633,401	704,574	774,926	842,813	915,738
	REDUCED ROI	37.8%		RED NPV	1,086,537										
1333	CF-PH I,SAVINGS @ 80%,LOW USE	(263,040)	(232,070)	(149,143)	(5,389)	129,912	133,200	339,960	369,802	401,858	436,293	473,283	513,017	555,700	601,550
	REDUCED ROI	25.3%		RED NPV	460,541										

SOURCE: Office of Technology Assessment

Table B-19

Cash Flows for Option F: Cancel

DATE	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
PHASE I ONLY CASH FLOW	54,469	34,884	33,426	35,717	31,126	33,436	35,916	38,581	41,444	44,519	47,823	51,371	55,183	59,277

NPV 232,199

SOURCE: Office of Technology Assessment

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Office of Technology Assessment

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